U.S.-PAKISTAN CENTER FOR ADVANCED STUDIES IN ENERGY (USPCAS-E)

"Use of Covered Conductors in Medium Voltage Power Transmission"

Presented By

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References Provided in the end

Presenter's Introduction

Researcher/Presenter

Dr. Syed Ali Abbas Kazmi

Assistant Professor in EPE, USPCAS-E (2017 to date)
Topics: Smart Distribution Networks Planning and scheduling; Smart Grids, MG, MMG, VPP, EPS

PhD in Electrical Power Engineering,
SKKU (2013-2017);

MS in Electrical Power Engineering,
UET Peshawar (2010-2012);

BS in Power Engineering,
UET Taxila (2004-2008)

Content of the Presentation

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Introduction

History of Conductors in Power Systems

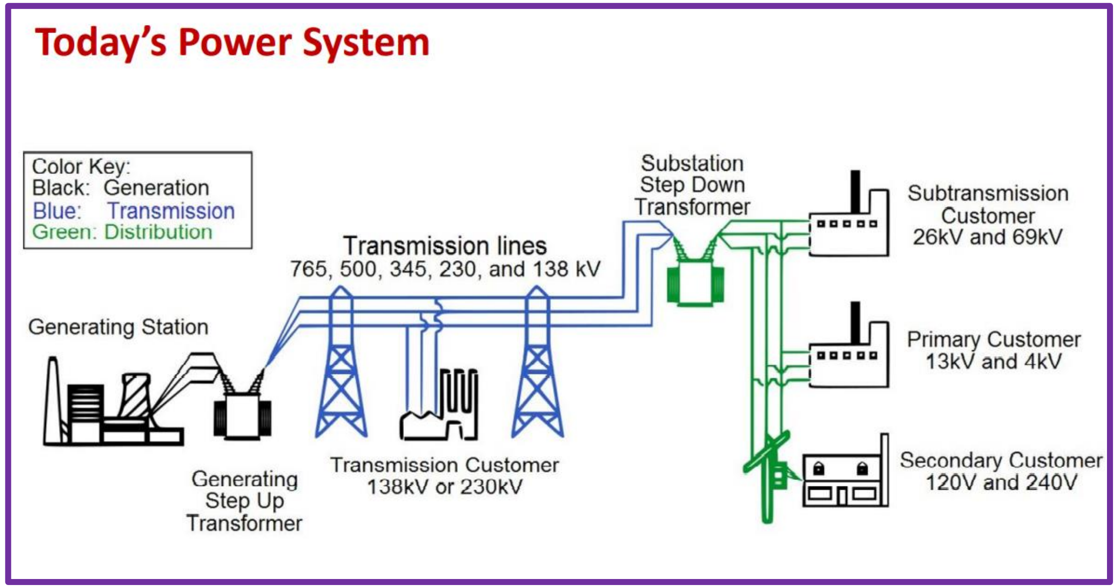
- **First real practical use of electricity began with the telegraph (1860s) and then arc lighting in the 1870s**
- **Early 1880s – Edison introduced Pearl Street DC system in Manhattan supplying 59 customers**
- **1884 – Sprague produces practical DC motor**
- **Mid 1880s – Westinghouse/Tesla introduce rival AC system (War of Currents)**
- **1885 – invention of transformer**
- **Late 1880s – Tesla invents AC induction motor**
- **1893 – Three-phase transmission line at 2.3 kV**
- **1896 – AC lines deliver electricity from hydro generation at Niagara Falls to Buffalo, 20 miles away; also 30kV line in Germany**
- **Early 1900s – Private utilities supply all customers in area (city); recognized as a natural monopoly; states step in to begin regulation**
- **By 1920s – Large interstate holding companies control most electricity systems**

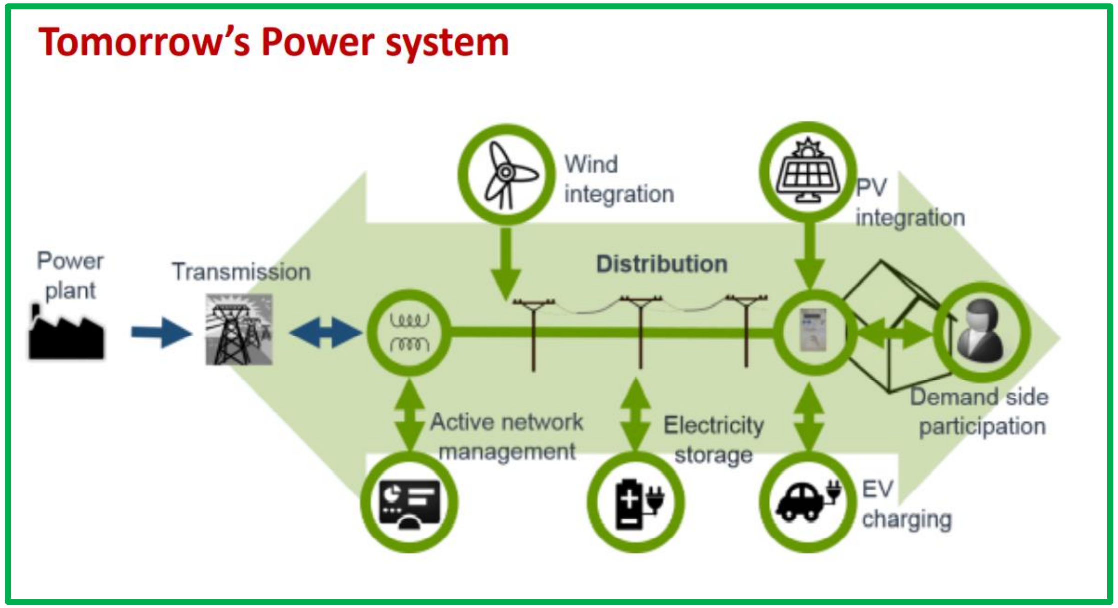
Power System Transformation

Power System of Today

Power System of Future

Each Segment Matters





Types of Conductors

What are the types of Conductors in MV transmission?

Broadly classified as:

1. Bare Conductor (Overhead or OH)

2. Underground Cable (Underground or UG)

3. Covered Conductor (CC)

Figure. Illustration of Bare OH, UG Conductor, and Covered OH Conductors

Bare Conductors

Bare Conductors

- Medium voltage distribution networks (MVDN) largely use bare (uninsulated) conductors, which have the following attributes:
  - ❖ Easy installation and economical maintenance.
  - ❖ In comparison, low economic burden.
  - ❖ Can easily looped between poles and are composed of various materials.
  - ❖ Over-headed in nature and resides on the roadside poles
  - ❖ Collective length of the whole assembly provides a suitable ground clearance for the conductors

- However, bare conductors are susceptible to the risk of failure and may impact environmental vicinity.

- Bare conductor that falls within contact distance of immediate undergrowth in the surrounding area may result in:
  - ❖ Grounding path for bare live conductors
  - ❖ Damage to the conductors through arcing
  - ❖ Cause fire

Bare Conductors, Contd.

- For the falling bare conductor Tree branches may provide a high resistance path that may not operate protection devices, however, the low current can cause the conductor fibers to ignite and fall down on the ground, thus starting fire and causing safety issues on ground.



- Possible Solution:
  - ❖ Insulated/Covered conductor systems for distribution

Underground Conductors

Underground Conductors

- Underground (UG) conductors/cables are used for power applications where it is impractical, difficult , or dangerous to use the OH lines.
  - ❖ They are widely used in densely populated urban areas, in factories, and even to supply power from the overhead posts to the consumer premises.

- Usefulness of using underground cables:
  - ❖ Suitable for congested urban areas with installation issues
  - ❖ Low maintenance
  - ❖ Small voltage drops
  - ❖ Fewer faults
  - ❖ Not susceptible to shaking and shorting due to vibrations, wind, accidents, etc.
  - ❖ Not easy to steal, make illegal connections or sabotage
  - ❖ Poses no danger to wildlife or low flying objects.

Underground Conductors, Contd.

- Issues regarding using underground cables:
  - ❖ More expensive than OH conductors (2 to 6 times as per application)
  - ❖ Fault identification sometime becomes challenging
  - ❖ Difficult to repair the broken UG cables
  - ❖ Damage to UG cables is possible incase of any construction process.
  - ❖ Electrocution may occur to people if unaware of live UG cable existence.

Covered Conductors

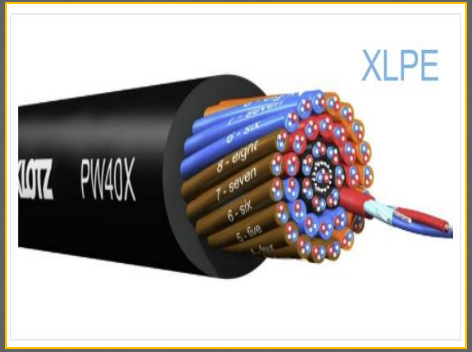
Covered Conductors

- Lie between OH bare conductors and Covered UG conductors.
  - **European Committee for Electro-technical Standardization** Std. EN 50397 (CC up to 36 kV)
  - Def: “It consists of a conductor surrounded by a covering made of insulating material as protection against accidental contacts with other covered conductors and with grounded parts.”
  - Comprises of single core conductors with a variety of insulation layers and outer sheath coverings

- Covered conductors (CC) types used at distribution voltages usually includes:
  - Cross-Linked Polyethylene (XLPE) and High Density Polyethylene (HDPE)
  - Aerial cable systems
  - Spacer Cable concept

3. Covered Conductors, Contd.

- CC types used at distribution voltages include:
  - **XLPE / HDPE based CC**
    - **Single or multiple sheathed.**
    - **Most common sheath materials.**
    - **Conductors: Cu, Al, ACSR, AACSR, etc.**
  - **Spacer cable**
    - **It is three CC phases in a polymeric support cradle**
    - **Supported by a ‘messenger’ cable.**
    - **Spacer on the right hand side**
  - **Aerial cable**
    - **Its insulated 3-core cable with an earth screen.**
    - **Used for both OH and UG applications.**



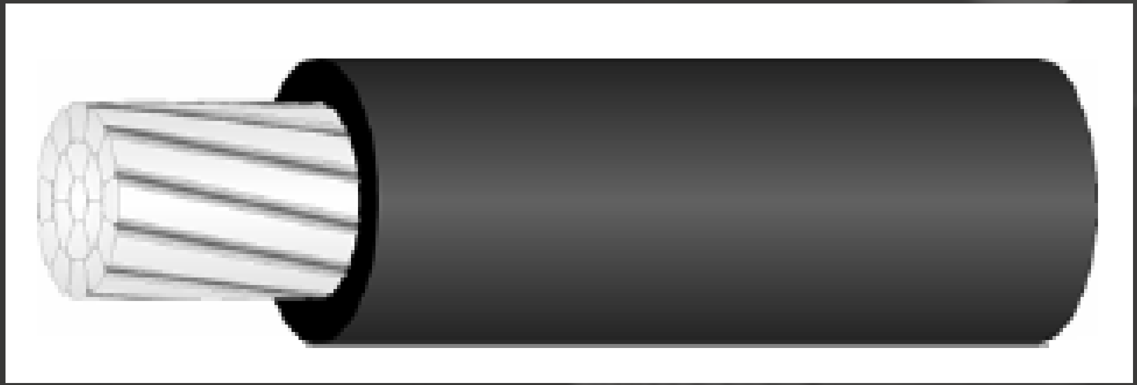


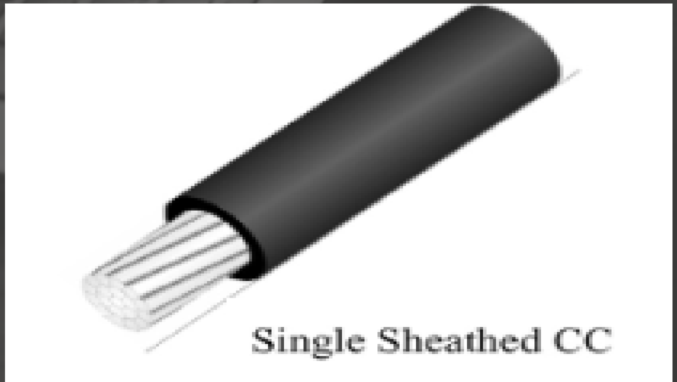
Covered Conductors Type-1

Covered Conductors Types

Single sheath CC: The characteristics of single sheath CCs are:

- Typically low density XLPE and covers thickness up to 3.3 mm till 33KV
- Normally use aluminum alloy conductors (AAC) with an XLPE or HDPE sheath of 2.3mm thickness.
- 1.6 mm thick sheath for ACSR and 1.8 mm thick sheath for AACSR
- Cu is used in extremely salt-polluted environments.
- HDPE sheathed conductor is used in coastal environments with less carbon %.
- Provides some resistance to outages caused by tree and wildlife contact.
- The thinner sheaths reduce the overall diameter, that leads to lower vibration levels.





Covered Conductors Types, Contd.

Multiple sheath CC: The characteristics of multiple sheath CCs are:

- Two or three sheath layers at medium voltage (6.6-33kV)
- The three layers (Figures below) corresponds to:
  - Semi-conducting sheath (A) close to the metal conductor to equalize out the electric field
  - An insulating polyethylene sheath (B)
  - A hard abrasion-resistant outside layer of HDPE (C)
  - KESC (Baldiya and Liyari for Theft control)

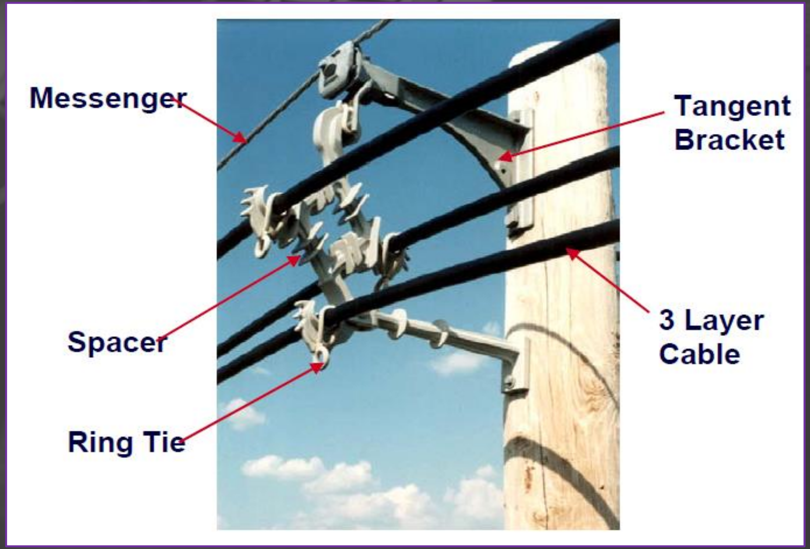
Multiple Sheathed CC

Covered Conductors Type-2

Covered Conductors Types, Contd.

Spacer cable

- It is three CC phases in a polymeric support cradle
- A messenger-supported 3 layer cable construction in a close triangular configuration
- The mechanical strength to weather severe storms
- The electrical strength to prevent faults due to phase to phase or phase to ground contact, tree contact or animal contact
- A complete coordinated system including cable, messenger, spacers, insulators and hardware



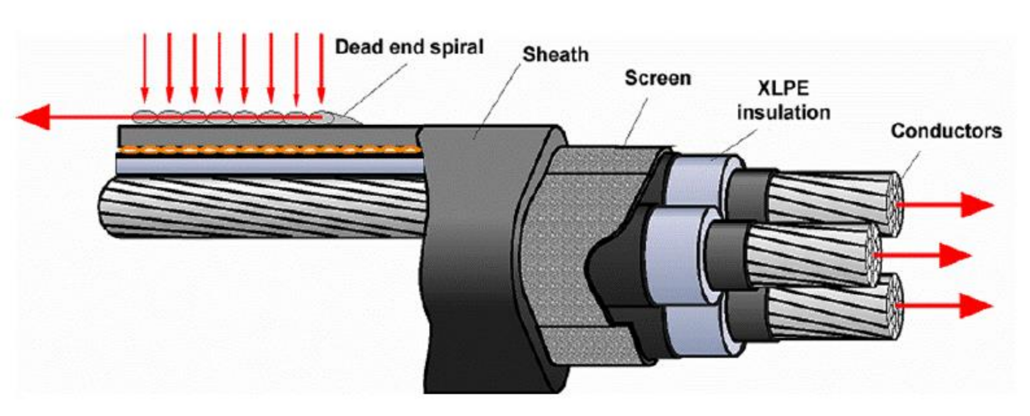
Covered Conductors Type-3

Covered Conductors Types, Contd.

Aerial cable

- The features of aerial cable are:
  - It is insulated 3-core cable with an earth screen
  - Used for OH applications.
  - Fully shielded three core power cables
  - Excellent contact resistance
  - Go overhead, underground, underwater
  - Less voltage drop than CC and bare
  - Weather resistant aerial bundled cable (AAC or AAAC or ACSR) and neutral Conductor

  .



Covered Conductors Types, Contd.

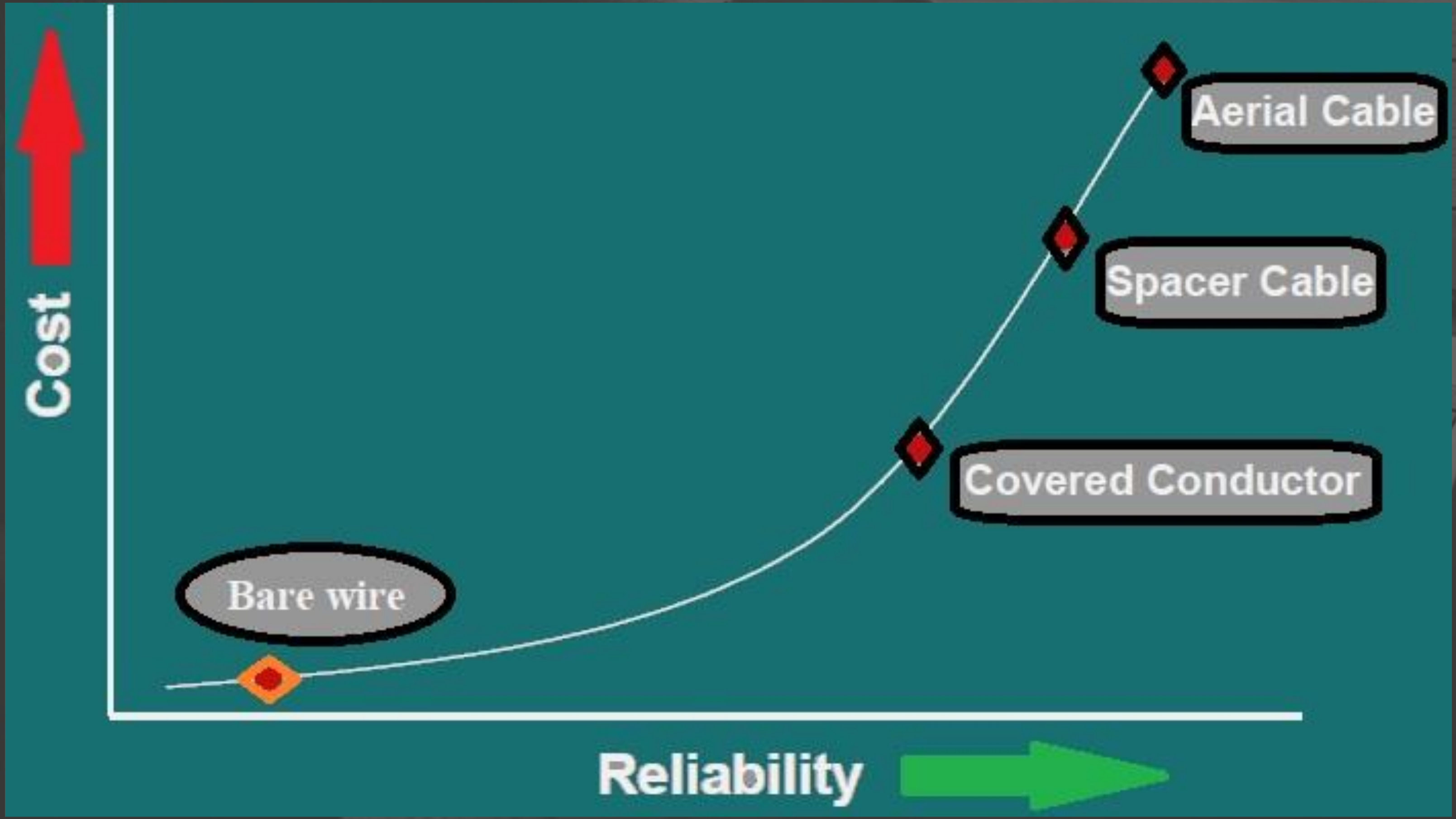


Fig. Comparison of schematic reliability of conductors

Advantages of CC

Covered Conductors, Contd.

- The advantages attributed to OH CC are shown as follows:
  1. Reduce the probability of contact between live conductors and surrounding materials
  2. Reduce the overall technical losses due to direct hooking and theft.
  3. Reduction in maintenance cost of the system.
  4. Decreases the spread of hazardous non – linear electric fields.
  5. Increases the stability of the voltage and current profiles through the distribution lines
  6. Decrease in the probability of power outages.
  7. Improve the quality of the delivered power to the consumers
  8. Improve the reliability of the network operationally and economically.

Monthly Tripping in IESCO (Data: 2017)

IESCO

TRIPPING (MONTHLY)

23

JULY 2017 IN R/O IESCO SATELLITE TOWN DIVISION.

Sub Division	LENGTH OF 11 KV LINE		NO. OF TRIPPINGS				NO. OF TRIPPINGS PER 100 KM					
			BELOW 20 MIN:		ABOVE 20 MIN:		BELOW 20 MIN:			ABOVE 20 MIN:		
	PRV:	PRES:	PRV:	PRES:	PRV:	PRES:	PRV:	PRES:	INC/DEC	PRV:	PRES:	INC/DEC
Asghar Mall	49.42	49.42	56	79	4	8	113.31	159.85	INC	8.09	16.19	INC
F-Block	72.88	72.88	153	129	19	23	209.93	177.00	Dec	26.07	31.56	INC
Chandni Chowk	68.67	68.67	163	104	25	13	237.37	151.45	Dec	36.41	18.93	Dec
Muslim Town	34.37	34.37	65	71	10	7	189.12	206.58	INC	29.10	20.37	Dec
Gangal	75.89	75.97	256	195	35	27	337.33	256.68	Dec	46.12	35.54	Dec
Dk:Kala Khan	28.57	28.57	63	74	6	2	220.51	259.01	INC	21.00	7.00	Dec
Division	**329.80**	**329.88**	**756**	**652**	**99**	**80**	**229.23**	**197.65**	**Dec**	**30.02**	**24.25**	**Dec**

EXECUTIVE ENGINEER (E) IESCO

Monthly Tripping in IESCO (Data: 2019)

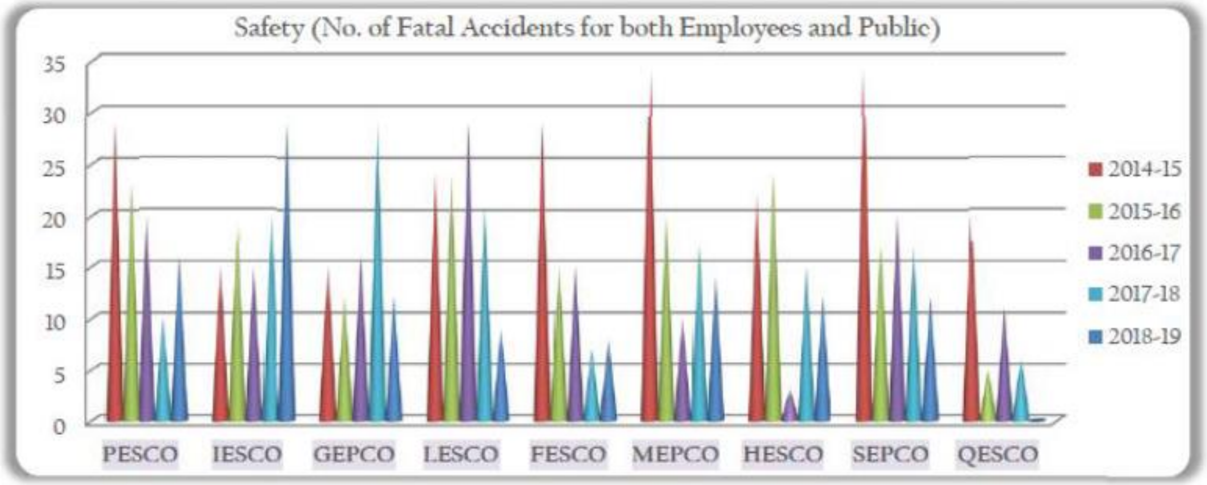
ISLAMABAD ELECTRIC SUPPLY COMPANY

Performance Standard (Distribution) 1st Quarterly Performance Report - - - - - (07/2019- 09/2019)

Performance Data 11 K V (Independent Feeders) (Without Load Shedding)

Sr: No.	Name of Circles	A: No. of 11KV Feeders	A: Total No. of 400/230 Volts Consumers	B: Consumer Annual Total Short Interruptions	C: Consumer Annual Total un-planned long interruption	D: Consumer Annual long un-planned interruptions duration (Hrs)	E: Consumers Annual Total No. of Planned Interruption	F: Consumer Annual Planned Interruption Duration (Hrs)	G: Un-planned Interruptions restored within 10 (Hrs) (GS1)	H=C-G: Restored after 10 (Hrs)	I: PMT No. of un-planned Interruption Annual (GS2)	J: No. of consumers whose un-planned supply interruption exceeded PMT (GS2)	K: Max PMT Agrt duration un-planned annual Hrs (GS3)	L: No. of consumers who exceeded Agrt limit (GS3)	M: Max PMT No. of planned interruptions (GS4)	N: No. of consumers who exceeded limit of Agrt planned interruption (GS4)	O: Max PMT Agrt duration planned annual Hrs (GS5)	P: No. of consumers who exceeded Agrt limit (GS5)	Q: Max PMT short duration (GS6)	R: No. of consumers who exceeded limit (GS6)	S = B+C+E: Total interruptions annual	T = Bx3+ Dx60+Fx60: Annual aggregate sum of all consumers interruptions duration (Mnts)	U=S/A: SAIFI	V=T/A: SAIDI
1	Islamabad	171	236	1707	132	38	24	71	1839	0	7.5	0	11	0	2	0	16	0	35	0	1863	11661	7.89	49.41
2	Rawalpindi	61	82	758	63	8	0	0	821	0	7.5	0	11	0	2	0	16	0	35	0	821	2754	10.01	33.59
3	Attock	18	18	107	48	23	0	0	155	0	7.5	0	11	0	2	0	16	0	35	0	155	1701	8.61	94.50
4	Jhelum	7	7	115	17	30	17	43	132	0	7.5	0	11	1	2	2	16	2	35	1	149	4761	21.3	680
5	Chakwal	11	11	258	40	77	0	0	298	0	7.5	1	11	1	2	0	16	0	35	1	298	5394	27.09	490.4
IESCO TOTAL		268	354	2945	300	176	41	114	3245	0	7.5	1	11	2	2	2	16	2	35	2	3286	26271	9.28	74.21

Accidents in MV Discos of Pakistan



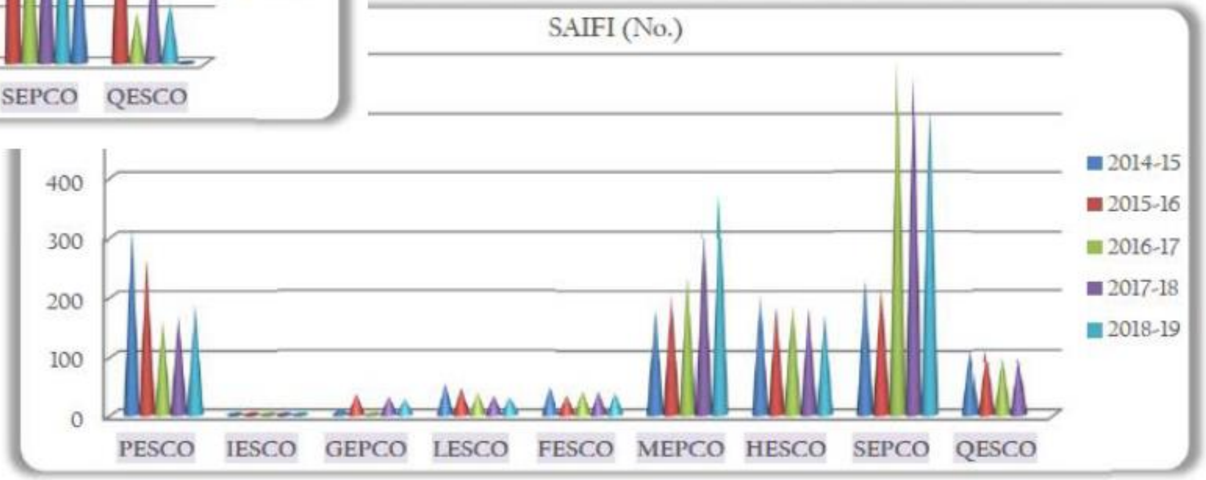


Chart source: NEPRA State of the Industry Report 2019

Problem Formulation

Problem Formulation of CC

- The Problem formulation of CC utilization usually aims at reduction of the associated costs:

  - The additional costs of operational damages and poor quality of the delivered energy to the consumer needs to be strongly decreased.

  - The transmission system will not afford any external costs that are associated with:
    - Cost of maintenance vehicles that are utilized to solve very dangerous faults,
    - Cost of planes that are utilized to make difficult repairs
    - Wages of the excessive labor to work in extreme climate conditions with more time waste

  - A great savings in money will be achieved that will increase the reliability and enhance the economics of the MV transmission system that utilized CCs.

Problem Formulation of CC, Contd.

- Methodology to calculate the total cost of the medium transmission system that utilized CCs is:
  - The law of Kelvin procedures that states “the total cost of the transmission system is divided into two major categories in eqn. 1 (with possible addition of other costs in eqn.2)”.
  - The first one involves the capital costs that are independent of the cross sectional area (CSA) of the utilized CC cables or any other element of the network
  - The second involves the costs that are directly associated with the CSA of the utilized CC cables

$$C_T = C_C + C_O \tag{1}$$

where.

C_T is the total cost of medium transmission lines that utilized CCs.

C_C is the total capital cost during installation that are independent of CSA of CC cables.

C_O is the other costs that are related to CSA of CC cables.

$$C_T = \int_{t=0}^{n} [C_C(t) + C_F(t) + C_R(t)]\, dt \tag{2}$$

where.

C_F is the initial fixed costs that involve the costs of outages or faults.

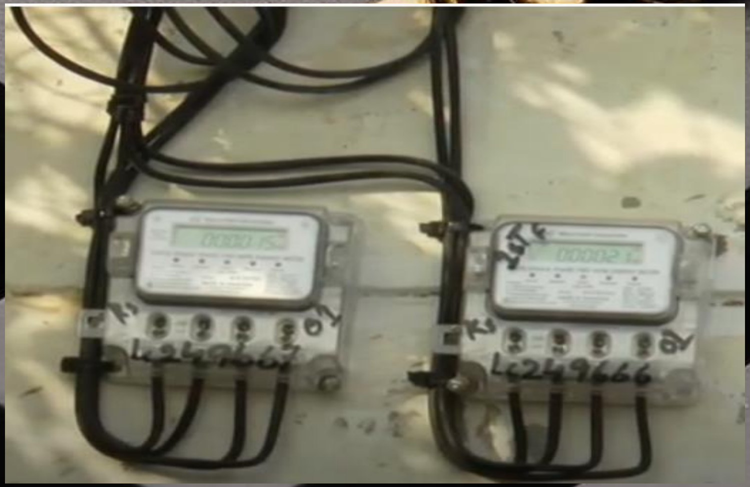
C_R is the total running operating costs.

n is total lifetime of the system that utilized CCs.

On ground Impact at a Glance

On ground Impact at a Glance

- Scope of Installation: (1) LT service main (440 V); (2) 11KV MV feeder
  - Implemented at LT in two sub-divisions of MEPCO. (1) Multan Circle City S/D; (2) DG Khan Circle
  - Implemented at both LT and MV level in KESC → Project Ujala
    - KESC Aerial ABC CC Project (Project Ujala) worth around 150 Million USD
    - CNEEC was the EPC contractor, that executed the project
  - K-Electric (KESC) implemented this project at the following locations in Karachi.
    - Gulshan-e-Iqbal
    - Bhittai Colony
    - Liaqat Market (Malir)
    - PKT Colony (Defense)
    - Naval Colony (Baldia)
  - Immediate Effect: In Gulshan-e-Iqbal alone, losses drastically reduced to 80% of initial value and 90% area was exempted from load shedding.
    - Puncturing of ABC cables is extremely difficult and pilferage (direct hooking) was reduced to zero



KESC is among the Pioneers of CC in Pakistan (Installation and Operations)

Source: https://www.youtube.com/watch?v=4pyV9fXZv-8

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Forum is open to Discussion