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A Practical Approach of Reducing Dielectric Losses and Calculation of an Existing 33KV HV-UG Power Cable of a Distribution Network

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Abstract: *The aim of the analysis is to reduce dielectric losses in HV-UG Cable Distribution network system in an economical way. Since Residential and Industrial developments are getting faster growth rate, the load demand also gets varied day by day. Now a days, Load duration hours are also critically changed and resulting heavy voltage fluctuations that create critical issues in Power Quality, Stability and Security. Due to space and corridor issues, Over Head Lines are getting replaced with Under Ground Cables in heavily populated industrial areas for safe and easy transmission. But Long cable Power Transmission generates certain unavoidable losses but it can be minimized by VAR Compensator and also it helps the system to maintain the voltage profile within limits. In this paper, the total power loss calculation for 24 hours in the existing network is investigated and installed suitable VAR Compensator for minimizing the power loss in the Network. In this research analysis, using ETAP modeling results proved that the total power saving per day was nearly equal to 2471 KW. Hence the practical approach was good agreement.*

Keywords: *Power cable, Cable Parameters, power factor calculation, VAR compensator, power loss, ETAP modeling*

I. Introduction

High Voltage power cable is widely used in power system industry in all over the world. The effective application of power cable has extensively increased in the last few decades. At present, the power cable manufacturing industry provides reliable quality in manufacturing with newly advanced technologies on considering the increasing load demand and customer satisfaction. The typical life of high voltage power cable design can withstand 50- 80 years. Most of the power cable and extra high voltage underground - power cable (EHV-UG Cable) were increasing the failure of fault, the aging of the cable, range of input supply, loading of the cable, mismatch of load, spacing between conductor wires and touching of the cable. During the operation of Power cable, the high AC current transmission is not evenly disposed throughout the cable length and cross sectional area of the cable. Hence the power cable gets loaded with high heat which will be disputed the total length of the cable and operates quietly in order to calculate sheath circulating loss and sheath circulating eddy current loss. This assembly is comprised to measure total losses for the Power cable in connection with the inductive load like induction motor. The non-uniform distribution sheath current, voltage between sheath to ground and sheath to conductor are significantly affecting the total losses of the power cable, the power cable is normally covered with the metallic sheath whereas the sheath is coated with high insulating layer to protect and prevent the cable core from the mechanical damage and moisture. The different factors affecting the sheath losses in the single core cable are studied in the paper [2]. The electrostatic field is enclosed between the conductor and sheath have been presented in the technical literature[3].The middle of the power are non-uniform distribution of power loss and dielectric loss which produced due to the account of proximate effect are studied in the paper [4]. The dielectric loses or insulation losses are effectively very small and it can be neglected in the range of more than 66kv [5]. The eddy current losses which present inside the solid toroid are perfectly calculated [6] under loading conditions, the main heat sources inside the cable such as eddy current losses and joule losses which are very critical for calculating thermal distribution and capacity of UG cable are studied in the article [7]. The different factors affecting the losses in the cable due to the circulating current flowing through the cable sheath. A detailed mathematical calculation is used for the computation of cable sheath loss found in [8- 10]. The power cable screen sheath of a conductor induced the switching current and voltage to generate undesirable power loss due to the skin and proximate effect. It is our duty to provide safe with quality and required uninterrupted quantity of power to a consumer who pays money for electricity. For that we need power quality in Power Generation, Transmission, and Distribution. For Transmission of Power, OHL takes major role in Long Transmission. However in Urban Areas, Underground cable distribution system is an alternative solution to distribute electrical energy in the heavy populated cities. This UG cable system helps the city to view neat, clean and also safe. However, UG-Cable is costlier than underground cable. This paper mainly focuses the detailed study of the power cable for different losses and practical approaches towards loss reduction technique are implemented and the results compared using ETAP Simulation

II. Cable Losses Calculation:

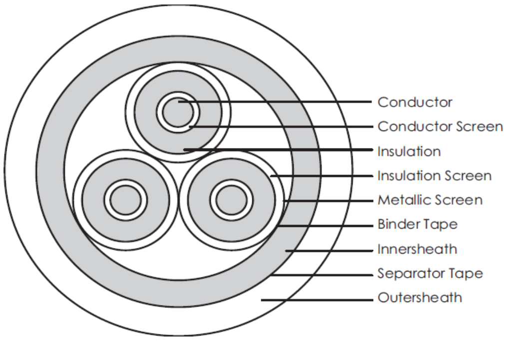

Figure 1 Power cable structure

The numerical AC power losses of a single layer and double layer in the power cable between conductors are calculated by FEM-based models. The offset DC current does not contribute to the power losses in AC when total currents become lesser than the critical currents. The power losses depend on the magnitude of the AC quantity are proved in the literature [11]. An underground power cable is constructed by a dielectric material sheath inside the conductor. Hence the electric current flows the power cable gets energized by voltage and current due to the large capacitance effect between the conductor to conductor and conductor to sheath that produced a heat around the power cable. The sheath eddy current losses are inversely proportional to sheath resistance, and cable conductor resistivity, the conductor spacing is proportional to the conductor current in the UG power cable whereas the sheath circulating losses are directly proportional to the conductor spacing and current flowing through the conductor. The thermal effect increases throughout the power cable whereas the generation and dissipation of heat along the power cable leads to different losses for which occurred, are known as conductor losses, dielectric losses and sheath losses.[11 12]. Dielectric losses are occurred in the power cable. It is classified as Voltage-dependent and current-dependent components.

2.1 Voltage-Dependent Power Losses

The supply voltage is applied across a perfect dielectric which leads no dielectric loss in practice. Then the perfect dielectric cannot produce dielectric losses in the AC power cable which are proportional to phase voltage, frequency, capacitance to neutral and power factor. Voltage-dependent power losses are caused by polarization effects within the main insulation and P_D is calculated by

$P_D = V_o^2 \omega C_o \tan\delta$ Watts/Km (1)

Where

V_0 = Operating voltage in KV

ω = Angular frequency

C_0 = capacitance to neutral in µF/km

While in the three core power cable, the dielectric losses are $3P_D$ in watts. The dielectric power loss factors tan δ is varied from cable insulations which dependent on supply frequency, temperature and supply voltage

2.2 Current-Dependent Power Losses

The current-dependent losses are basically dependents on Ohmic conductor losses and sheath losses which includes sheath eddy current loss and sheath circuit loss. These losses are accounted through skin effect and proximity effect.

2.2.1. Ohmic conductor losses

The ohmic losses depend on the ac current flowing through the power cable, the resistance of the conductor material and temperature effect of the cable conductor. The ohmic losses or variable losses are calculated by R I^2. The conductor resistance R stated for 20^0C (R_0) must be converted to the operating temperature θ of the cable:

$R = R_o[1 + \alpha[\theta - 20^0c]]$ (Ω/km) (2)

Where
α= 0.0393 for Copper
α= 0.0403for Aluminium
The conductor cross-section and admissible DC resistances at 20^0C 22(R_0) corresponds to the standard series pursuant to IEC 60228.

2.2.2 Sheath losses

The UG power cables are equipped with metal sheaths or screens that must be earthed adequately. Sheath losses occurred through the cable mainly the Circulating currents in the system and Eddy currents in the cable sheath which applicable only for tubular types power cable. The sheath currents are caused by induced sheath voltage. The ac current flowing through cable conductor and sheath, for which the EMF induced by each end of the cable are bounded from closed loop. It cuts magnetic line of flux in the sheath and depends upon the spacing between the sheath return path current through the earth. The sheath of a single-core cable is bonded to earth or to other sheaths at more than one point, where a current flows in the sheath due to the EMF induced by the AC. conductor current by 'transformer' action. This is because the sheath and return path to each end of the sheath is bonded to form a closed loop cut by the flux associated with the current in the conductor. The magnitude of the flux which cuts the sheath is dependent on the size of the loop which in turn, is dependent on the spacing between the cables or between the sheath and the mean return path of the current through the earth or other medium. The total sheath losses in the power cable are calculated to measure the sum of the sheath current losses and sheath eddy current losses.
The sheath current losses per phase are calculated as

$$S_{sheath\ current\ loss} = \frac{I^2 X_m^2 R_s}{R_s^2 + X_m^2} \frac{w}{Km} \quad (3)$$

The sheath Eddy current losses per phase are calculated as

$$S_{sheath\ eddy\ current\ loss} = I^2 \left[\frac{3\omega^2}{R_s} \text{ EMBED Equation.3 } \right] \text{W/Km (4)}$$

The sheath total losses per phase are calculated as

$$S_{sheath\ total\ loss}\ I^2 R_S[\text{ EMBED Equation.3 }] \text{ W/Km (5)}$$

Where

I =conductor current in amps
ω = 2π multiplied by frequency
d_m = mean diameter of the sheath (m)
D = distance between cable center (m)
R_s= sheath resistance (Ω/km)

The voltage induced in the sheath is

$$E_S = IX_m$$
$$X_m = 2\pi f M \times 10^{-3}$$

Where I = Conductor current (A)
The mutual inductance M between conductor and sheath is given by

$$M = 0.2 \log_e\left(\frac{2D}{d_m}\right) \quad \text{(mH/km) (6)}$$

The sheath current (Is) is calculated from the below equation

$$I_s = \frac{E_s}{\sqrt{R_S^2 + X_m^2}} = \frac{IX_m}{\sqrt{R_S^2 + X_m^2}} \quad (7)$$

Where Rs is the sheath resistance (Ω/km). The sheath current losses per phase is given by

$I_s^2 R_s = \dfrac{I^2 X_m^{\ 2} R_s}{R_s^{\ 2} + X_m^{\ 2}}$ (watt/km) (9)

$I_s^2 R_s = \dfrac{I^2 X_m^{\ 2} R_s}{Z_S^2}$ (watt/km) (10)

Z_S= sheath impedance of the cable (Ω/km)
I_s = sheath current in amps
R_s= sheath resistance Ω/km

III. Power Cable Parameter Calculation:

3.1. Cable Inductance

The inductance (L) of a 3-core cable comprises two parts such as the self-inductance of the conductor and the mutual inductance between the conductor to conductor. The inductance is given by

$L = K + 0.2 \log_e \dfrac{2S}{d}$ (mH/km) (11)

K = constant relating to the conductor formation (table 1)
S = axial spacing between conductors within the cable (mm),
Or axial spacing between conductors of a trefoil group
of single-core cables (mm), or = 1.26 × phase spacing
for a flat formation of three single-core cables (mm)
d = conductor diameter for a shaped designs or the diameter of
an equivalent circular conductor (mm)
For 2-core, 3-core and 4-core cables, the inductance obtained from the formula should be multiplied by 1.02 if the conductors are circular or sector-shaped and by 0.97 for 3-core oval conductors.
Table 1 Typical values for constant K for different stranded conductors (at 50 Hz)[29]

Table 1

Number of wires in conductor	K
3	0.0778
7	0.0642
19	0.0554
37	0.0528
61 and over	0.0514
1 (solid)	0.0500
Hollow-core conductor, 12 mm duct	0.0383

3.2. Cable Impedance

In this method, the cable impedance parameter is calculated from the following formula

$$Z_{selfimpedanceconductor} = R_{dc} + R_{er} + jk_{ff} \log\left[\frac{D_{er}}{GMR_{pc}}\right] \Omega / km \quad (12)$$

$$R_{dc} = \rho_{cu} \frac{1000}{S_{cu}} = \frac{(17.8e^{-6})}{n\pi\left(\frac{d}{2}\right)^2} \Omega / m \quad (13)$$

$$R_{er} = \pi^2 \omega^{-4} f \Omega / km$$

$$k_{ff} = 0.173522 f \quad \Omega / km$$

$$GMR_{pc} = r.\exp(\mu_r / 4)$$

$$D_{er} = 1650\sqrt{\rho_{cu} / 2\pi f}\, m$$

$$\rho_{cu} = 17.8e^{-9} \Omega / m$$

Z_{sp} is the self-impedance of the phase conductor

R_{DC} is the dc resistance of the phase conductor,
R_{er} is the resistance of the earth return path,
K_{ff} is the frequency factor
GMR_{pc} is the geometric mean radius of phase conductor,
r is the radius of the conductor
μ_r is the relative permittivity of the conducting material.
f is the frequency in Hertz
D_{er} is the distance of equivalent earth return path,
ρ_{cu} is the resistivity of phase conductors
n is the number of strands in the phase conductors
f is the nominal frequency of the cable,
d is the diameter of one strand in meter

$$Z_{selfimpedancescreen} = R_x + R_e + jK_{ff} \log\left(\frac{D_{er}}{GMR_x}\right)\Omega / km \qquad (14)$$

$$R_x = \rho \frac{1000}{s} \Omega / km$$

$$GMR_x = \frac{r_{ext} - r_{\text{int}}}{2}$$

Where
Z_{ss} is the self-impedance of the screen conductor.
R_x is the dc resistance of the phase screen conductor
GMR_x is the geometric mean radius of phase screen insulator ρ is the resistivity of the conductor,
r_{ext} is the external radius of phase and screen insulator, r_{int} is the internal radius of the phase to screen insulator The mutual impedance between the phase and screen is calculated as follows

$$Z_{mutualphasescreen} = R_{er} + jk_{ff} \log\left(\frac{D_{er}}{D_n}\right)(\Omega / km) \qquad (15)$$

Where
Z_{ps} is the mutual impedance between the phase and screen conductor D_n is the distance between the phase conductor and mean radius at phase screen insulator.

The mutual impedance for n phase conductor is calculated as shown below where n is greater than one

$$Z_{mutualphaseconductor} = R_{er} + jk_{ff} \log\left(\frac{D_{er}}{GMD}\right)\Omega / km \qquad (16)$$

$$GMD = \sqrt[n]{\prod_1^n d_{xy}}$$

Where
Z_{xx} is the mutual impedance between the phase conductors,
n is the total number of conductors.
GMD is the geometric mean distance of the phase conductor set to all other conductors. It is represented by a symbol $D_{m.}$ D_m is the Distance between the phase conductor and set of cables.

3.3. Cable Capacitance Calculation

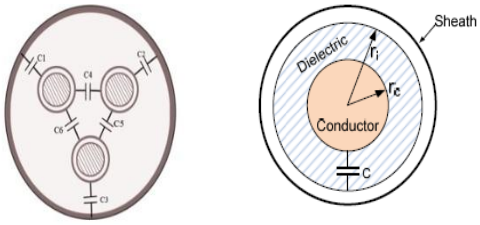

Figure 2 cable capacitance coupling

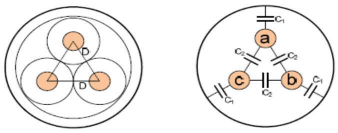

Fig Three core capacitance model

Medium voltage and high voltage cable may be single-core cable with an earthed metallic layer around the core or 3-core cable with an earthed metallic screen around each core. In both cases, the electrostatic field is constant within the earthed screen and is substantially radial. Power cable capacitance between conductor to conductor and conductor to sheath are calculated as follows

C_{cs} = Capacitance between conductor to conductor

C_{cc} = Capacitance between conductor to sheath

The potential of the star point terminal is nearly equal to zero. The equivalent capacitance between the star point and core is $C_{CN} = 3C_{cc}$ the capacitance of the each conductor to neutral

$$C_N = C_{CS} + 3C_{cc} \qquad (17)$$

$$C_{CC} = \frac{C_B}{2} - \frac{C_A}{6} \qquad (18)$$

$$C_N = \frac{C_A}{3} \qquad (19)$$

$$C_N = \frac{C_A}{3} + 3\left(\frac{C_B}{2} - \frac{C_A}{6}\right) = 3\frac{C_B}{2} - \frac{C_A}{6} \qquad (20)$$

The capacitance between conductor 1, 2, and third conductor to sheath is

$$= C_{CC} + \frac{C_{CC}}{2} + \frac{C_{CS}}{2} = \frac{3C_{CC}}{2} + \frac{C_{CC}}{2} = \frac{1}{2}(3C_{CC} + C_{CS}) \qquad (21)$$

IV. Calculation Of Sending End And Receiving End Voltages (In Terms Of Real Powers In transmission Line)

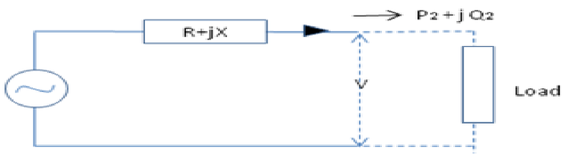

Figure 4 Single line diagram

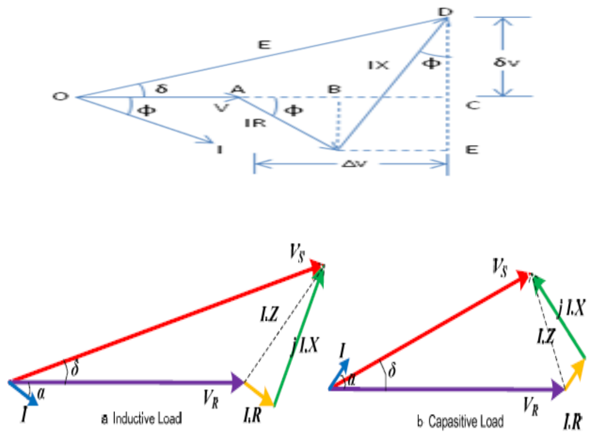

Figure 5 Vector Diagram

V_R= Voltage at receiving end,
V_S=Voltage at sending end,
R_L=Line Resistance,
X_L=Line Reactance,
Z_L=Line Impedance,
I_L= Line current,
θ = phase angle between V and I at R End
δ= phase angle between VRE andVSE

$$VSE^2 = \left[V + \frac{P_{2R}}{V} + \frac{Q_{2X}}{V}\right]^2 + \left[\frac{P_{2X}}{V} - \frac{Q_2 R}{V}\right]^2 \quad (22)$$

$$= \frac{P_{2R}}{V} + \frac{Q_{2X}}{V} \rightarrow \Delta V = \frac{P_2 R + Q_2 X}{V} \quad (23)$$

$$\delta V = \frac{P_{2X - Q_{2R}}}{V} \quad (24)$$

$$E^2 = \left[V + \frac{P_2 R + Q_2 X}{V}\right]^2 \quad (25)$$

$$E = V + \frac{P_2 R + Q_2 X}{V} \quad (26)$$

$$E - V = \frac{P_2 R + Q_2 X}{V} = \Delta V \quad (27)$$

Hence the arithmetic difference between sending end and receiving end is given below

$$\Delta V = \frac{P_2 R + Q_2 X}{V} \quad (28)$$

If R resistance of the line neglected $\Delta V = \frac{Q_2 X}{V} \quad and \quad \Delta V \infty Q_2$ (29)

$$\sin\delta = \frac{CD}{OD} = \frac{\delta V}{E} \quad (30)$$

When X>>R, $\delta V = \frac{P_2 V}{E}$ (31)

$\delta V \infty P_2$

The power flow between sending end and receiving end terminal is calculated by a transmission angle δ .The reactive power is determined by difference between sending end and receiving end voltage

V. Gauss-Seidel Method Of Algorithm

Load flow studies involve solution of the equation

$$S_n = V_n I_n \ \ and \ I_n = \sum_{k=1}^{r} Y_{nk} V_k \qquad (32)$$

Eliminating the **In** in the above equation (32)

For each node n = 1 to r (33)

$$\frac{S_n}{V_n} = \sum_{k=1}^{r} Y_{nk} V_k = \sum_{k=1}^{n-1} Y_{nk} V_k + Y_{nn} V_n + \sum_{k=n+1}^{r} Y_{nk} V_k \qquad (34)$$

Calculate V_n^*

$$V_n^* = -\sum_{k=1}^{n-1} \frac{V_{nk}^* Y_n^*}{Y_{nn}^*} \sum_{k=n+1}^{r} \frac{Y_{nk}^* V_k^*}{Y_{nn}^*} + \frac{S_n}{V_n Y_{nn}^*} \qquad (35)$$

$$V_n^{*p+1} = -\sum_{k=1}^{n-1} \frac{V_k^{*p+1} Y_{nk}^*}{Y_{nn}^*} \sum_{k=n+1}^{r} \frac{Y_{nk}^* V_k^{*p^*}}{Y_{nn}^*} + \frac{P_n}{V_n^p Y_{nn}^*} \qquad (36)$$

V_n^* voltage at n node, V_n^{n+1} voltage at p+1 node

(37)

At p+1th iteration cycle (36) can be evaluated. Q_n can be calculated from Eqn.(37) by adding with the voltage magnitudes

$$\left[Re\left\{ \left(V_n^{*p+1}\right)^* + \frac{jQ_n}{V_n^p Y_{nn}^*} \right\}^2 + Im\left\{ (V_n^*)^* + \frac{jQ_n}{V_n^p Y_{nn}^*} \right\}^2 \right]$$

$$= |V_n|^2 \qquad (38)$$

Eqn (38) is solved for Q_n and this value is substituted into Eqn. (37) to give the improved estimate for the generator node voltage

VI. Indian Power System Standard:

Voltage variations occur in the power grid is due to the mismatch in the reactive power between MVAR-demand and MVAR-available. Any variations in the parameters of voltage and frequency below the operating limits considered as unhealthy for power grid and restoration steps will be taken to make the power grid healthy in Electrical Power System Network. The range of operating frequencies and voltages are given in the tables.

Table 2 Indian Frequency Permissible limits

S. No.	HZ-Normal	Hz-min	Hz-max
1	50Hz	49.2Hz	50.3Hz

Table 3 Indian Steady State Voltage Permissible limit:

S. No.	KV-Normal (kV rms)	KV-Max (kV rms)	KV-Min (kV rms)
1	765 KV	800 KV	728 KV
2	400 kV	420 KV	380 KV
3	220 kV	245 KV	198 KV
4	132 kV	145 KV	122 KV
5	110 KV	121 KV	99 KV
6	66 KV	72 KV	60 KV
7	33 KV	36 KV	30 KV

VII. Method Of System Analysis:

The above method of system analysis is carried out by a world well known and recognized software of ETAP USA. The systematic calculation has done from the bottom level of the project preliminary study like visiting the proposed 132/33KV substation and also along the root marking of all the cables to study the soil resistivity. The geographical data collection of various temperatures and also rain recorded in particular site location which is based on the above data. The following design activity carried out is as follows .Preparation of load schedule, estimation of power demand and design of the single line diagram (SLD) for sizing the transformer breaker cable etc. Project Designing in ETAP Load Flow Analysis was done at four Levels

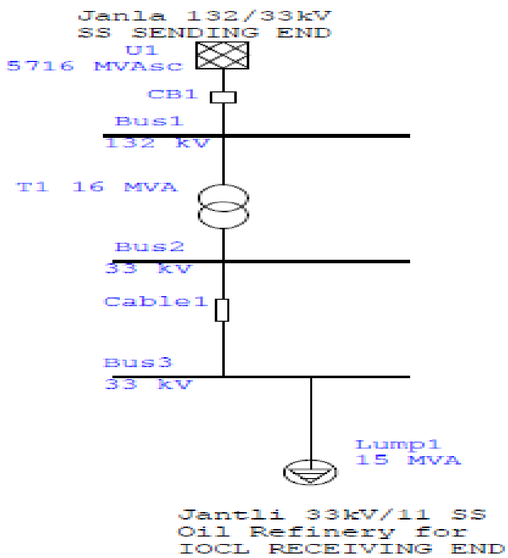

Figure 6

VIII. Result And Discussion

Indian standard has fault current level limitation in various voltage levels. The Fault current level for LV -0.440KV system is 50KA for 1 second, the Fault current level for 3.3kv and 6.6 KV system are approved as 40KA. Moreover the Fault current level for 11kv ,33kv and above are strictly restricted only upto 25 KA The impartment equipment involved in this project is shown in SLD. Since isolator circuit breaker and other protective device are not contributing in the circuit operation for this analysis, those devices are completely discarded. Our main aim of research is to minimize the losses in the major power system elements like cable, transformer and load so that our power system SLD has been simplified as per the requirement of technical paper submission. The technical parameter/dated/equipment /element required for analysis of the system is tabulated as follows

Table 4

Utility(or)Grid	
Input voltage	33kv
FAULT current	25KA
Short circuit MVA	5716
X/R ratio	14

Table 5

Transformer	
Primary Input voltage	132kv
Secondary output voltage	33kv
Reactive power	16mva
X/R ratio	18.6
Impedance	8%

Table6

Power cable	
Cable model	3core
Conductor size	120sqmm
Conductor material	Copper
Cable capacity	36 kv
Insulation	XLPE
Distance	10km

Table 7

Load parameter	
Type of load	Motor 15mva
Power	12 mw
Reactive power	9 mva
Power factor	80%
Current rating	262.4A
Locked rotor current	650%
X''D	15.3%
Type of connection	Delta

The above mentioned data were entered in ETAP and the different study cases were analysed. The worst and best scenario wizards are generated in ETAP. Load flow analysis were carried out under the following four impartment worst scenarios based on the different loading conditions and 24 Hours Events Recorded . Motor Operated on OLTC was provided in transformer for AVR and also Shunt Compensator provided for compensating losses at light load and peak load conditions. The table (8) gives the Comparative Analyses statement for 24 Hours. Table (9) Shows Loss analysis calculation for four event and Table (10) indicates the total loss calculation analysis for 24 Hours. Figure (11) shows the Power loss comparison in the entire network system with and without compensator. Figure (12) shows the total Power loss variation in transformer with and without compensator. Figure 13 shows the total Power loss in line bus 3 with and without compensator.Figure14 shows the Power loss variation in cable with and without compensator Figure 15 shows the Power loss in the comparison line bus 2 with and without compensator

8, 1 Analyzing Very Worst conditions and Selecting for 4 Worst scenarios
EVENT NO 1
NIGHT 1AM

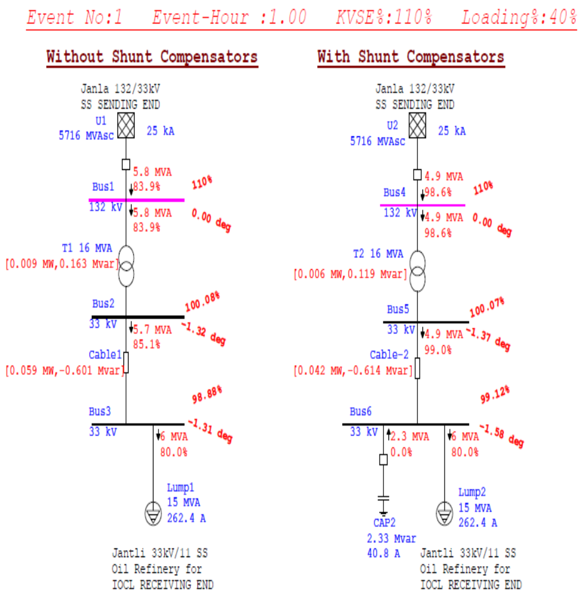

Figure 7with and without Compensator
Event-1 occurs at Night 1.00 am ETAP Model is recorded

Without compensator
BUS 1 Sending End KV is found 110% of 132KV (145.2KV)
BUS2 Sending End KV is found 100.08%0f33KV (33.026KV)
BUS 3 Sending End KV is found 98.88% 0f 33KV (32.63KV)
Loading End is found only 40% of 15MVA. (6MVA). At this moment, the losses are recorded in Transformer 0.009MW + j0.163MVAR and cable losses are recorded 0.059MW - j0.601MVAR

With compensator Capacitor bank added 2.33 MVAR
BUS1 Sending End KV is found 110% of 132KV (145.2KV)
BUS2 Sending End KV is found 100.07%0f 33KV(33.023KV)
BUS3 Sending end KV is found 99.12% 0f 33KV (32.70KV)
Loading End is found only 40% of 15MVA. (6MVA). At this moment, the losses are recorded in Transformer 0.006MW + j0.119MVAR and cable losses are recorded 0.042MW- j0.614MVAR

EVENT NO 5
MORNING at 5AM

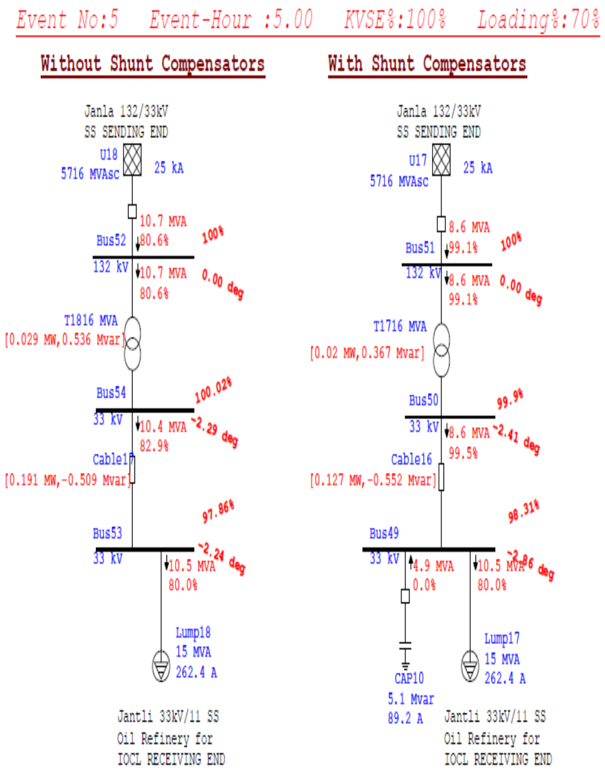

Figure 8 with and without Compensator
Event-5 occurred at 5am in the morning for which ETAP Model was recorded

Without compensator
BUS 1 Sending End KV is found 100% of 132KV (132.2KV)
BUS 2 Sending End KV is found 100.02%0f 33KV (33.06KV)
BUS 3 Sending End KV is found 97.86% 0f 33KV (32.29KV)
Loading End is found only 70% of 15MVA.(10.5MVA). At this moment, the losses are recorded in Transformer 0.029MW + j0.576MVAR and cable losses are recorded0.191MW - j0.509MVAR

With compensator Capacitor bank added 5.1 MVAR
BUS 1 Sending End KV is found 100 % of 132KV (145.2KV)
BUS 2 Sending End KV is found 99.99%0f 33KV (32.96KV)
BUS3 Sending End KV is found 98.31% 0f 33KV (.32.44KV)
Loading End is found only 70 % of 15MVA.13.5MVA). At this moment, the losses are recorded in Transformer 0.02MW +j0.367 MVAR and cable losses is0.127MW - j0.552MVAR

EVENT NO8
MORNING at 8AM

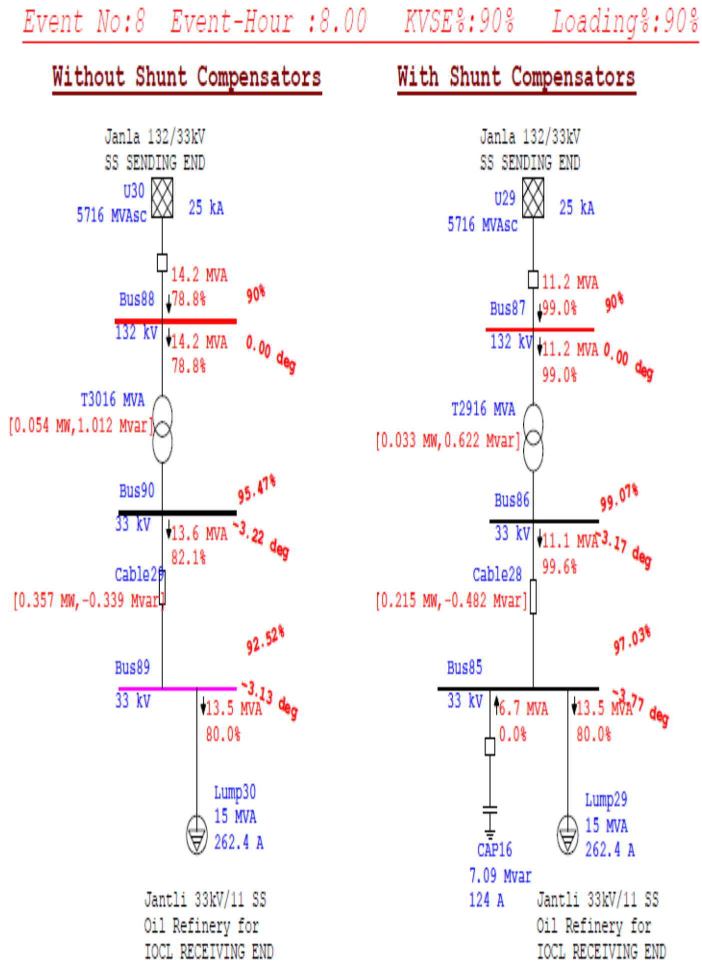

Figure9 With and without Compensator
Event- 8 occurs atmorning 8.00am ETAP Model is recorded

Without compensator
BUS 1 Sending End KV is found 90% of 132 KV (118.8KV)
BUS 2 Sending End KV is found 95.47 %0f 33 KV (31.50KV)
BUS3 ending End KV is found 92.03 % 0f 33KV (30,36KV)
Loading End is found only 90% of 15MVA. (13.5MVA). At this moment, the losses are recorded in Transformer 0.054MW +j1.012 MVAR and cable losses is0.357MW - j0.339MVAR

With compensator Capacitor bank added 7.09 MVAR
BUS 1 Sending End KV is found 90 % of 132 KV (118.82KV)
BUS2 Sending End KV is found 99.07%0f 33KV (32.69KV)
BUS 3Sending End KV is found97.03%0f 33KV (32.O9KV)
Loading End is found only 90% of 15MVA. (13.5MVA). At this moment, the losses are recorded in Transformer 0.033MW + j0.622MVAR and cable losses are 0.215W - j0.482MWAR

EVENT NO 19
MORNING at 19 PM

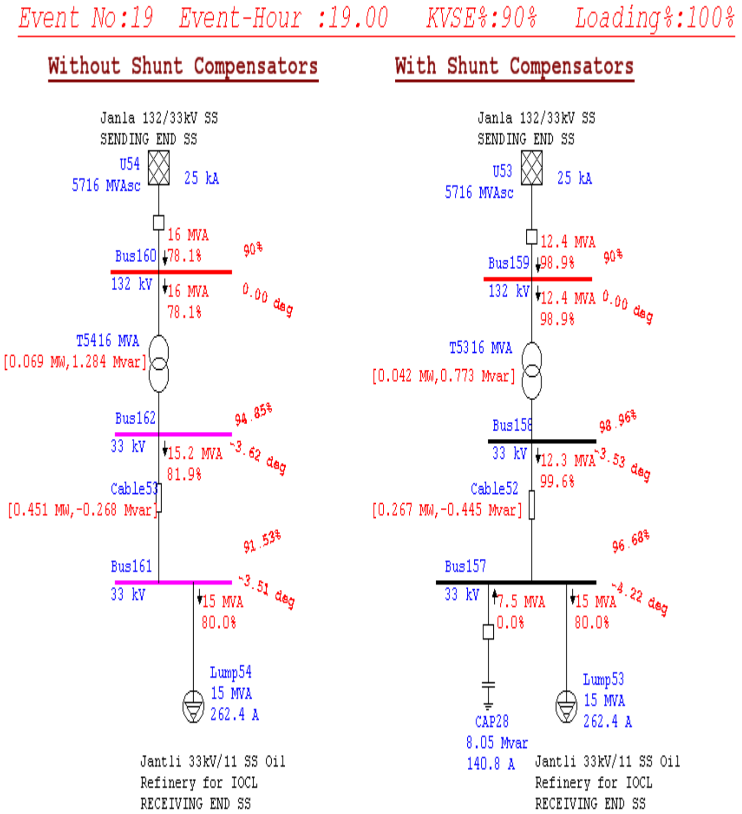

Figure 10 with and without Compensator
Event–19occured at 19.00 pm in the evening for which ETAP Model was recorded

Without compensator
BUS 1Sending End KV is found 90% of 132KV (118.8KV)
BUS 2Sending End KV is found 94.85 %0f 33KV (31.18 KV)
BUS3Sending End KV is found 91.53 % 0f 33KV (30.20KV)
Loading End is found 100 % of 15MVA.(15MVA). At this moment, the losses are recorded in Transformer 0.069MW + j1.284MVAR and cable losses is0.451MW - j0.268MVAR

With compensator Capacitor bank added 8.055 MVAR
BUS 1 Sending End KV is found 90 % of 132KV (118.8KV)
BUS 2 Sending End KV is found 98.96 %0f 33KV (32.65KV).
BUS 3 Sending end KV is found 96.68 %0f 33KV (31.94KV)
Loading End is found only 100% of 15MVA. (15MVA). At this moment, the losses are recorded in Transformer 0.042MW +j0.773MVARand cable losses are 0.267MW - j0.0445MVAR

Table: 8 Comparative Analyses statement 24 Hours

Event	With out-Compensator			With- Compensator			MW	PF
	Bus1	Bus2	Bus3	Bus1	Bus2	Bus3		
	kV%	kV%	kV%	kV%	kV%	kV%		
1	110	100.8	98.8	110	100.7	99.12	4.9	0.851
2	108	99.98	98.39	108	99.85	98.64	6.3	0.839
3	106	100.1	98.27	106	100.3	98.94	7.3	0.834
4	102	102	100.3	102	100.4	98.52	8.2	0.83
5	100	100.2	97.86	100	99.99	98.31	8.6	0.829
6	98	100.3	97.48	98	100.3	98.23	11.1	0.823
7	104	100.1	97.15	104	99.9	97.77	11.8	0.822
8	90	95.47	92.52	90	99.07	97.03	11.2	0.821
9	95	99.83	97.02	95	99.73	97.7	11.1	0.823

10	96	99.95	96.97	96	100.1	98.01	11.8	0.822
11	95	99.83	97.02	95	99.75	97.73	11.1	0.823
12	93	98.72	95.71	93	100.3	98.22	11.8	0.821
13	90	95.47	92.52	90	99.07	99.03	11.2	0.821
14	90	99.83	97.02	90	99.8	97.79	11.2	0.823
15	90	94.98	91.73	90	98.97	96.74	12.2	0.819
16	90	94.91	91.63	90	98.95	96.69	12.3	0.819
17	90	94.85	91.53	90	98.96	96.68	12.5	0.819
18	90	94.85	91.53	90	98.96	96.68	12.5	0.819
19	90	94.85	91.53	90	98.96	96.68	12.5	0.819
20	95	100	96.88	95	99.62	97.35	12.4	0.821
21	98	99.99	97.02	98	100.3	98.13	11.8	0.822
22	100	100.3	97.53	100	99.7	97.66	11.1	0.823
23	105	99.97	97.48	105	99.78	97.97	9.9	0.826
24	110	100.3	98.42	110	99.87	98.48	7.2	0.834

Table:9 Losses calculation Analyses

Event No	Event Hours	KV Sending End %	Receiving End Loading	Transformer Loss with out compensation	Transformer Loss compensation	Cable Loss with out compensation	Cable Loss with ompensation
1	1 Hours	110% (145.2KV)	40% (6MVA)	0.009MW + j0.163MVAR	0.006MW + j0.119MVAR	0.059MW - j0.601MVAR	0.042MW - j0.614MVAR
5	5 Hours	100% (132KV)	70% (10.5MVA)	0.029MW + j0.576MVAR	0.02MW + j0.367MVAR	0.191MW - j0.509MVAR	0.127MW - j0.552MVAR
8	8 Hours	90% (118.8KV)	90% (3.5MVA	0.054MW + j1.012MVAR	0.033MW + j0.622MVAR	0.357MW - j0.339MVAR	0.215W - j0.482MVAR
19	19 Hours	90% (118.8KV)	100% (15MVA)	0.069MW + j1.284MVAR	0.042MW + j0.773MVAR	0.451MW - j0.268MVAR	0.267MW - j0.0445MVAR

Table 10 Total losses calculation analysis for 24 Hours

Event ID	Without Compensator						With Compensator					
	TR-Loss		CL-Loss		**Total**		TR-Loss		CL-Loss		**Total**	
	kw	kvar	kw	kvar	**kw**	**kvar**	kw	kvar	kw	kvar	**kw**	**Kvar**
1	9	163	59	-601	68	-438	6	119	42	-614	48	-495
2	15	285	103	-569	118	-284	11	203	71	-591	82	-388
3	21	386	138	-546	159	-160	14	267	93	-581	107	-314
4	26	486	173	-524	199	-38	18	335	116	-562	134	-227
5	29	536	191	-509	220	27	2	367	127	-552	129	-185
6	49	907	32	-423	81	484	33	607	21	-5	54	602
7	55	1020	36	-395	91	625	37	682	236	-478	273	204
8	54	1012	357	-339	411	673	33	622	215	-482	248	140
9	49	916	324	-416	373	500	33	613	212	-492	245	121
10	55	1024	361	-391	416	633	36	678	234	-482	270	196
11	49	916	324	-416	373	500	33	613	212	-492	245	121
12	57	1053	371	-369	428	684	36	675	233	-486	269	189
13	54	1012	357	-339	411	673	33	622	215	-482	248	140
14	49	916	324	-416	373	500	33	611	211	-494	244	117
15	66	1226	431	-283	497	943	4	741	256	-452	260	289
16	67	1255	441	-275	508	980	41	758	262	-448	303	310
17	69	1284	451	-268	520	1016	42	773	267	-445	309	328
18	69	1284	451	-268	520	1016	42	773	267	-445	309	328
19	69	1284	451	-268	520	1016	42	773	267	-445	309	328
20	61	1140	402	-365	463	775	41	762	263	-456	304	306
21	55	1023	361	-392	416	631	36	676	234	-484	270	192
22	32	906	32	-424	64	482	33	614	212	-491	245	123
23	38	712	252	-466	290	246	26	482	167	-524	193	-42
24	21	384	138	-548	159	-164	15	27	94	-575	109	-548

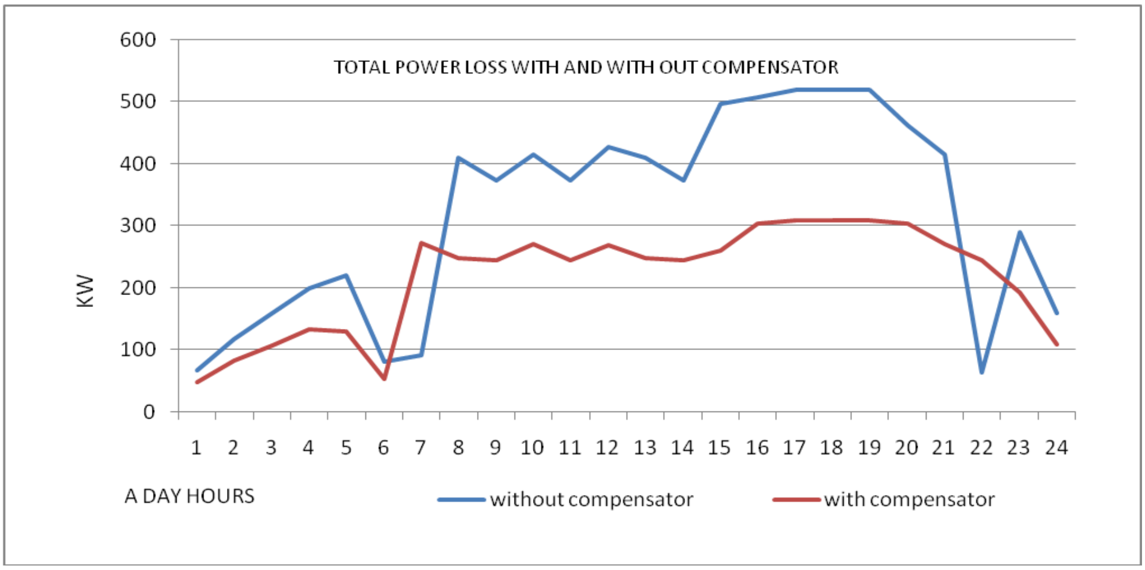

Figure 11 Total Power loss with and without compensator

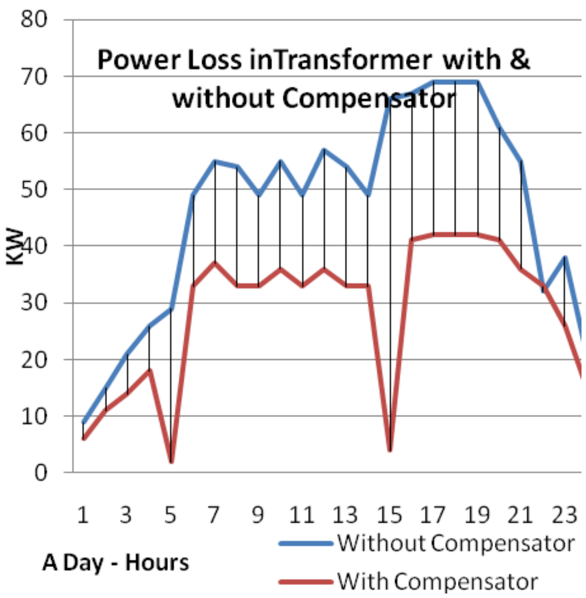

Figure 12 Power loss in Transformer With and without compensator

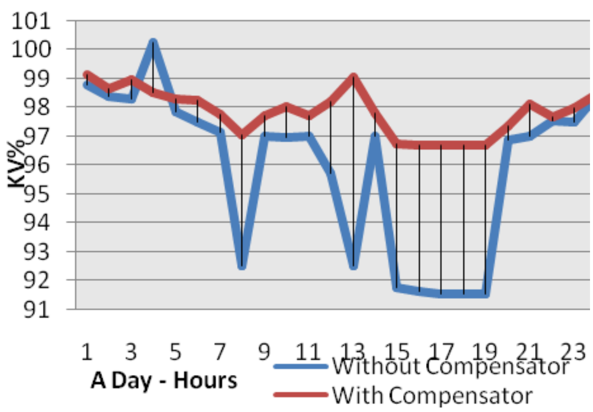

Figure 13 Power loss comparision after and befor compensator bus no 3

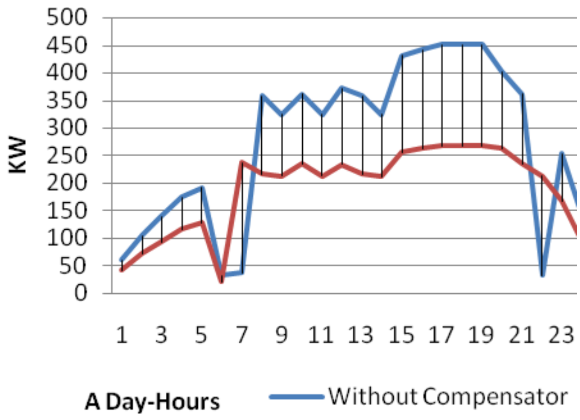

Figure 14 Power loss in cable With and without Compensator

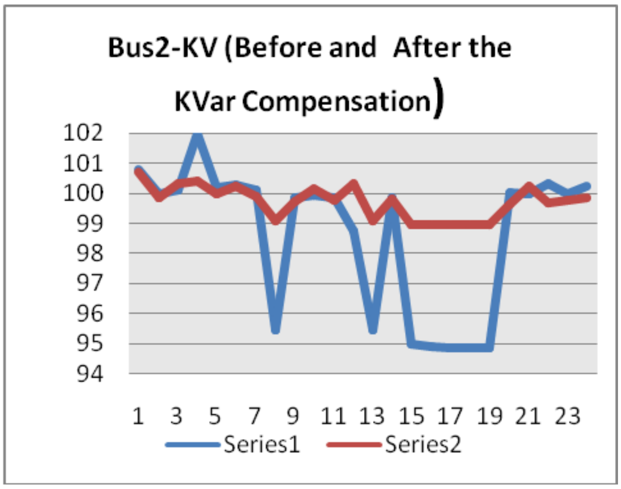

Figure 15 Power loss comparision after and befor compensator bus no 2

IX. Conclusion:

This Paper described the total Power loss compensation in the UG/HV Power cable. The power Loss was increased in the light load scenarios. Based on the analysis, the power loss in UG/HV 33KV long power cable was reached at the lowest level by optimizing the reactive power compensation.

The ETAP SLD simplified in different approaches for an efficient technique to compute total power losses. Which are effectively calculated for 24 hours in different peak and worst loading conditions. The total losses are calculated with and without compensator for a 10kM long three core 33KV XLPE UG power cable. The proposed methodology has been verified as bus 1, bus2, and bus3 for 24 hours in loading the power cable. The total power losses were calculated and also tabulated. The four methods of scenario event have been analyzed and predicted the losses in the research paper. Based on the description, it was investigated with and without adding the compensator on the load side. The total power losses were recorded as 7678 kW without compensator and with compensator was 5207 kW. The total power was saving per day equal to 2471 kW. The ETAP simulated results were compared with 24 hours measured data. It was shown good agreement for both practical and simulated measurements.

Reference

[1]. B. Novák1, L. Koller1 and I. Berta1 " Loss reduction in cable sheathing". European Association for the Development of Renewable Energies,Environment and Power Quality (EA4EPQ) Granada (Spain), 23th to 25th March, 2010

[2]. Osama ElsayedGouda,"AdelAbd-eltwabFarag"Factors Affecting the Sheath Losses in Single-Core Underground Power Cables with Two-Points Bonding Method" International Journal of Electrical and Computer Engineering (IJECE) Vol. 2, No. 1, February 2012, pp. 7~16 ISSN: 2088-8708

[3]. Abdel-Slam M., Anis H., El-Morshedy A, Radwan R "High Voltage Engineering Theory and Practice" " by Marcel Dekker, Inc., New York, 2000

[4]. NikšaKovač, George Anders, Fellow, IEEE, TomislavKilić, Member, IEEE "Sheath Loss Factors Taking into Account the Proximity Effect for a Cable Line in a TouchingFlat Formation" 2013 IEEE Transactions on Power Delivery

[5]. S. K. Kanikella, "Electric field and thermal properties of dry cable usingF EM," TELKOMNIKA, Vol. 11, pp. 2217-2230, May 2013.

[6]. DARIUSZ KOTERAS "Calculation of eddy current losses using the electro dynamic similarity laws "Archives Of Electrical Engineering Vol. 63(1), pp. 107-114 (2014)

[7]. F. De León, "Major factors affecting cable ampacity," Power Engineering Society General Meeting, IEEE, pp. 6, 2006

[8]. G.J Anders,Rating of electric power cable, NewYork, IEEEPress 1997

[9]. G.J Anders "Rating of electric power cable in unfavorable thermal environment" New Jersey IEEE Press/Wiley,2005

[10]. J.S.Barret and G.J Anders "Circulating current and hysteresis losses in screen, sheath and armour with IEC standard 287''IEEE.Proc.sci.Meastechnicalvol 144no 3pp101-110 may 1997

[11]. Y.H. Ma, J. Xu, Z. Yao, Z.Y. Li, Z. Jin, Z. Hong, and K. Ryu ''A Study on AC Losses of HTS Pentagonal Conductors Consisting of 2G Wires Carrying DC Offset Transport Current'' 1051-8223

[12]. Chae-Kyun Jung*, Jong-Beom Lee† and Ji-Won Kang** "Sheath Circulating Current Analysis of a Crossbonded Power Cable Systems"Journal of Electrical Engineering & Technology, Vol. 2, No. 3, pp. 320~328, 2007

[13]. IEC 62067, "Power cables with extruded insulation and the accessories for rated voltages above 150kV, Test methods and requirements"

[14]. Dong Dai, Mingli Hu, Ling Luo "Calculation of Thermal Distribution and Ampacity for Underground Power Cable System by Using Electromagnetic-Thermal Coupled Model"2014 Electrical Insulation Conference, Philadelphia, Pennsylvania, USA, 8 to 11 June 2014

[15]. IvicaStevanovic´, Bernhard WunschGian Luigi Madonna StanislavSkibin "High-Frequency Behavioral Multiconductor Cable Modeling for EMI Simulations in Power Electronics" IEEE Transactions On Industrial Informatics, Vol. 10, No. 2, May 2014

[16]. B. Wunsch, S. Skibin, and I. Stevanovic´, "Per-unit-length parameter extraction for lossy multi-conductor power cables," in Proc. EPEPS,San Jose, CA, USA, Oct. 27–30, 2013, pp. 1–4.

[17]. B. Wunsch, I. Stevanovic´, and S. Skibin, "Improved accurate high frequency models of multi conductor power cables exploiting symmetries," in Proc. EMC Europe, Brugge, Belgium, Sep. 2–6, 2013, pp. 332–337

[18]. Ken Kuen-Faat Yuen, and Henry Shu-Hung Chung "A Low-Loss "RL-Plus-C" Filter for Overvoltage Suppression in Inverter-Fed Drive System With Long Motor Cable" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 30, NO. 4, APRIL 2015

[19]. Yongchun Liang, Zhongjie Wang, Jianye Liu, Xiaoyun Sun "Reduction of Eddy Current Losses in Power Cable Systems Based on Phase Optimization" 978-1-4244-4813-5/10/$25.00 ©2010 IEEE

[20]. W.Rueger, G.Hosemann, "Improvement of Ampacity of Parallel Singlecore Cables by Uninsulated Additional Conductors", IEEE Transactions on Power Delivery, Vol.5, No.1, pp.33-39, January 1990

[21]. Karady, et.al.," A Novel Magnetic Field Management Method for Underground Power Cables", Electric Power System Research, Vol.31,No.2, pp.103-110, November 1994

[22]. H. Al-Khalidi, A. Kalam"Reduction in Sub-transmission Loss Using Underground Power Cables" 2008 Australasian Universities Power Engineering Conference (AUPEC'08)

[23]. 23] R.D. Roservear, "Power cables in 21st century energy development," Power Engineering Review, IEEE, 20(9), p. 8-10, 2000.

[24]. R. Kyoung-Soo, "An approach to allocate real power losses of transmission lines to individual loads," TENCON 99. Proceedings ofthe IEEE Region 10 Conference, 1999.2008

[25]. Jin Geun Kim, A.-Rong Kim, Daewon Kim, Minwon Park, In-Keun Yu, Jeonwook Cho, Ki-DeokSim,Seokho Kim, Jun Kyoung Lee, and Young-Jin Won "Development of a PSCAD/EMTDC modelComponent for AC Loss Characteristic Analysisof HTS Power Cable" IEEE Transactions On Applied Superconductivity, Vol. 20, No. 3, June 2010

[26]. Danish Khan, Muhammad Rafiq, Syed FurqanRafique, Idris Khan and Farukh Abbas "Comparison of transmission losses and voltage drops of GIL(Gas Insulated transmission line) and overhead transmission lines" 16th International Power Electronics and Motion Control Conference and Exposition

[27]. N.Shanmugasundaram ,Dr.S.ThangavelR,VajubunnisamBegum "Modeling Of Three Core Power Cable To Estimate Coupling Parameters With Overshoot Voltage In Induction Motor- Drives System Using Matlabsimulink " International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.29 (2015)

[28]. N.Shanmugasundaram, Dr.S.Thangavel, R.Vajubunnisabegum "Methodology for High Frequency Modeling of Power Cable to Estimate Reflection phenomenon in Long Fed ASD Induction Motor Drive System" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.5 (2015)

[29]. G.F Moore and B. C. Ltd, ElectricCables Handbook:Blackwell Science, 1997.

[30]. C.L.Wadhwa, Electrical Power Systems: New Age International, 2006