Distribution Network Element Model Parameters: Creation of Database

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***Abstract*—This paper reports a database of power delivery element model parameters required in specialized distribution network software packages. Based on the authors' experience, these parameters are seldom available or recorded by power utilities so that typical values must be used when modeling these elements. Due to space limitations, the parameters listed in this paper correspond to conductors, cables and distribution transformers mainly used in Costa Rica. To compensate this, an additional reference is presented to consider other power delivery elements and materials not included here.**

***Index Terms*—Data extraction, distribution network modeling, geographical information system, OpenDSS, smart grids.**

I. Introduction

The analysis of Distribution Networks (DN) requires advanced modeling tools able to represent virtually any power delivery element in Medium Voltage (MV) and Low Voltage (LV) grids [1]. The use of Geographical Information System (GIS) data allows power engineers to model more accurately their grids, as information of conductors lengths, capacity of distribution transformers and type of cables is usually available [2]. Unfortunately, parameters of these elements are seldom available so that typical values need to be used instead. These parameters are usually extracted from datasheets of some manufacturers that meet a technical standard, or even books. To the best of authors' knowledge, there are no publicly available, and truthful, databases that gathers information of conductors, transformers, and cables commonly used in DNs. To fill this gap, this paper presents a sample of a database built to be used in OpenDSS, a specialized DN software package [3]. The database presented in this paper is focused on power delivery elements mostly used in Costa Rica. However, it is likely that engineers in other regions can adapt or extrapolate these parameters for their own use.

This paper is organized as follows: Section II presents a summary of commonly used aluminium conductors in Costa Rica and how this information is used to build line models with the Carson's equations. Section III explains the cable parameters required to model MV concentric neutral cables. The typical parameters of distribution transformers and triplex cables are presented in Sections IV and V, respectively. Finally, the concluding remarks are presented in Section VI.

Table I
Typical electrical properties of AAC

Size #	Strands	GMR $[ft]$	r $[\Omega/kft]$	d $[in]$	$Ampacity$ $[A]$
$1/0$	7	0.0111	0.2000	0.368	247
$2/0$	7	0.0125	0.1590	0.414	286
$3/0$	7	0.0140	0.1260	0.464	331
$4/0$	7	0.0158	0.0999	0.522	383
266.8	19	0.0187	0.0793	0.592	444
336.4	19	0.0210	0.0630	0.665	513
397.5	19	0.0228	0.0534	0.723	570
477	19	0.0250	0.0445	0.792	639
556.5	19	0.0270	0.0382	0.856	703

II. MV and LV Overhead Lines

Most conductors used in MV and LV overhead lines are made of aluminium. These conductors are usually All Aluminium Conductors (AAC), All Aluminium Alloy Conductors (AAAC) and Aluminium Conductor Steel-Reinforced (ACSR) whose selection depends on mechanical factors.

The modeling of overhead lines requires the outside diameter d of conductors, their Geometric Mean Radius (GMR) and resistance r. For instance, Table I presents the typical electrical properties of some AAC conductors [4], [5]. Due to space limitations only the most common conductors used in Costa Rica are shown. In addition, Tables II and III present the typical electrical properties of some AAAC and ACSR conductors [6], [7], [8]. The sizes are specified in American Wire Gauge (AWG) or Million of Circular Mils (MCM), and the reported ampacities are based on $75°C$.

Without compromising significant accuracy, the modified Carson's equations can be used to calculate the elements of the primitive impedance matrix in $\Omega/mile$ of a line with n conductors [9], as follows:

$$z_{ii} = r_i + 0.0953 + j0.12134\Big(\ln\frac{1}{GMR_i} + 7.93402\Big) \quad (1)$$

$$z_{ij} = 0.0953 + j0.12134\Big(\ln\frac{1}{D_{ij}} + 7.93402\Big) \quad (2)$$

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Table II
TYPICAL ELECTRICAL PROPERTIES OF AAAC

Size #	Strands	GMR $[ft]$	r $[\Omega/kft]$	d $[in]$	$Ampacity$ $[A]$
1/0	7	0.0120	0.1947	0.398	256
2/0	7	0.0135	0.1545	0.447	296
3/0	7	0.0152	0.1227	0.502	342
4/0	7	0.0170	0.0973	0.563	395
266.8	19	0.0203	0.0769	0.642	460
336.4	19	0.0227	0.0610	0.720	532
397.5	19	0.0247	0.0518	0.783	590
477	19	0.0271	0.0431	0.858	663
556.5	19	0.0292	0.0371	0.927	729

Table III
TYPICAL ELECTRICAL PROPERTIES OF ACSR

Size #	Strands	GMR $[ft]$	r $[\Omega/kft]$	d $[in]$	$Ampacity$ $[A]$
1/0	6	0.0127	0.2170	0.398	242
2/0	6	0.0143	0.1760	0.447	276
3/0	6	0.0161	0.1440	0.502	315
4/0	6	0.0180	0.1190	0.563	357
266.8	24	0.0212	0.0782	0.633	455
336.4	24	0.0238	0.0621	0.710	525
397.5	24	0.0259	0.0526	0.772	584
477	24	0.0283	0.0439	0.846	655
556.5	24	0.0275	0.0376	0.914	721

where z_{ii} is the self impedance of the i^{th} conductor in $\Omega/mile$ while z_{ij} is the mutual impedance between the i^{th} and the j^{th} conductor, for $i \neq j$. In addition, GMR_i is the Geometric Mean Radius (in ft) of the i^{th} conductor, and D_{ij} is the distance (in ft) between conductors i and j. Note that r_i in (1) has to be specified in $\Omega/mile$, while the r presented in Tables I, II and III are given in Ω/kft.

The primitive impedance matrix is calculated when the spacing between overhead conductors is known. The information of conductor diameter and distances between conductors, and their images, is used to calculate the line capacitance, as explained in [10]. In the case of OpenDSS, the user must define the *wiredata* object based on Tables I, II and III, the *line spacing* and the *line geometry* [9] which depend on the actual wire height and spacing between conductors.

III. MV UNDERGROUND CABLES

MV underground cables are classified as concentric neutral and tape-shielded cables. In Costa Rica, only concentric neutral cables are used. Fig. 1 shows a simple detail of a concentric neutral cable. It consists of a central phase conductor (copper or aluminium) covered by a thin non-metallic semiconductor layer, called conductor shield, to which the insulating material (PVC, EP, EPR, XLPE) is bonded. This insulation is also covered by a semiconducting insulation screen and the k solid strands of concentric neutral are spiraled around the semiconducting screen with a uniform spacing between strands [10], surrounded by a covering jacket.

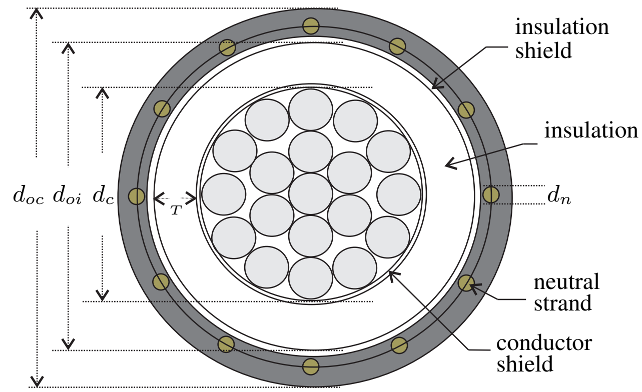

Figure 1. Concentric neutral cable

Some approximations need to be carried out before estimating the phase to ground capacitance and the self and mutual impedance of the phase conductor and the concentric neutral strands, for details see [10]. Tables IV to VII present the concentric neutral cable properties required to calculate the primitive impedance matrix and the shunt capacitance matrix of 15 kV and 35 kV underground lines with 100% insulation levels [11], [12], [13]. These parameters are also required in OpenDSS to model the cable with the *CNData* object. Due to space limitations aluminium cables and other MV voltages were not included in this paper. However, an extended database with aluminium cables is presented in [14].

Tables IV and V present the parameters of concentric neutral cables with neutral at 33%. These cables are mainly used for three phase systems. On the other hand, Tables VI and VII present the parameters for full (100%) neutral construction cables used for single phase systems.

The conductor size is specified in AWG or MCM. In addition, Fig. 1 should be recalled to identify the different diameters. For instance, d_c is the phase conductor diameter, d_{oi} is the diameter over insulation, d_n is the diameter of a single neutral strand and d_{oc} is the outer cable diameter, all in inches.

The cable insulation is specified by T and ϵ_r which are the thickness and relative permittivity of the insulation material, respectively. These parameters are of particular interest when calculating the shunt capacitance of MV underground cables. Note that $\epsilon_r = 3$ is valid for EPR insulation. Different insulation materials such as XLPE or PE typically have a $\epsilon_r = 2.3$ [15].

GMR_c and GMR_n stand for the GMR of the phase conductor and each of the k neutral strand, while r_c and r_n stand for the ac resistance (per unit length) of the phase conductor and dc resistance of one neutral strand, respectively. Finally, the cable ampacity may vary slightly for different manufacturers. It depends on ambient temperature, conductor temperature ($90°C$ in this database) and if the cable is direct buried or placed in ducts.

Table IV
15 kV NEUTRAL CONCENTRIC CABLE - 33% NEUTRAL, COPPER CONDUCTOR IN EPR INSULATION

Size #	d_c $[in]$	GMR_c $[in]$	r_c $[\Omega/kft]$	d_{oi} $[in]$	T $[in]$	ϵ_r	d_n $[in]$	GMR_n $[in]$	r_n $[\Omega/kft]$	k	d_{oc} $[in]$	$Ampacity$ $[A]$
1/0	0.373	0.141	0.10020	0.75	0.175	3	0.0641	0.0250	2.525	9	1.13	212
2/0	0.419	0.159	0.07949	0.80	0.175	3	0.0641	0.0250	2.525	11	1.17	241
3/0	0.470	0.178	0.06304	0.85	0.175	3	0.0641	0.0250	2.525	14	1.22	273
4/0	0.528	0.200	0.04999	0.90	0.175	3	0.0641	0.0250	2.525	18	1.28	309
250	0.575	0.221	0.04231	0.96	0.175	3	0.0808	0.0315	1.588	13	1.37	336
350	0.681	0.261	0.03022	1.06	0.175	3	0.0808	0.0315	1.588	18	1.49	398
500	0.813	0.313	0.02116	1.19	0.175	3	0.1019	0.0397	0.999	17	1.66	476
750	0.998	0.385	0.01410	1.38	0.175	3	0.1019	0.0397	0.999	20	1.94	547
1000	1.152	0.445	0.01058	1.53	0.175	3	0.1019	0.0397	0.999	26	2.12	620

Table V
35 kV NEUTRAL CONCENTRIC CABLE - 33% NEUTRAL, COPPER CONDUCTOR IN EPR INSULATION

Size #	d_c $[in]$	GMR_c $[in]$	r_c $[\Omega/kft]$	d_{oi} $[in]$	T $[in]$	ϵ_r	d_n $[in]$	GMR_n $[in]$	r_n $[\Omega/kft]$	k	d_{oc} $[in]$	$Ampacity$ $[A]$
1/0	0.373	0.141	0.10020	1.10	0.345	3	0.0641	0.0250	2.525	9	1.50	214
2/0	0.419	0.159	0.07949	1.15	0.345	3	0.0641	0.0250	2.525	11	1.54	248
3/0	0.470	0.178	0.06304	1.20	0.345	3	0.0641	0.0250	2.525	14	1.59	281
4/0	0.528	0.200	0.04999	1.25	0.345	3	0.0641	0.0250	2.525	18	1.65	317
250	0.575	0.221	0.04231	1.31	0.345	3	0.0808	0.0315	1.588	13	1.80	344
350	0.681	0.261	0.03022	1.41	0.345	3	0.0808	0.0315	1.588	18	1.90	407
500	0.813	0.313	0.02116	1.54	0.345	3	0.1019	0.0397	0.999	17	2.10	476
750	0.998	0.385	0.01410	1.73	0.345	3	0.1019	0.0397	0.999	20	2.32	565
1000	1.152	0.445	0.01058	1.88	0.345	3	0.1019	0.0397	0.999	26	2.47	625

Table VI
15 kV NEUTRAL CONCENTRIC CABLE - 100% NEUTRAL, COPPER CONDUCTOR IN EPR INSULATION

Size #	d_c $[in]$	GMR_c $[in]$	r_c $[\Omega/kft]$	d_{oi} $[in]$	T $[in]$	ϵ_r	d_n $[in]$	GMR_n $[in]$	r_n $[\Omega/kft]$	k	d_{oc} $[in]$	$Ampacity$ $[A]$
1/0	0.373	0.141	0.10020	0.75	0.175	3	0.0808	0.0315	1.588	16	1.16	210
2/0	0.419	0.159	0.07949	0.80	0.175	3	0.1019	0.0397	0.999	13	1.25	238
3/0	0.470	0.178	0.06304	0.85	0.175	3	0.1019	0.0397	0.999	16	1.30	268
4/0	0.528	0.200	0.04999	0.90	0.175	3	0.1019	0.0397	0.999	16	1.38	300
250	0.575	0.221	0.04231	0.96	0.175	3	0.1019	0.0397	0.999	25	1.41	336
350	0.681	0.261	0.03022	1.06	0.175	3	0.1285	0.0501	0.628	22	1.59	398
500	0.813	0.313	0.02116	1.19	0.175	3	0.1285	0.0501	0.628	31	1.78	476

Table VII
35 kV NEUTRAL CONCENTRIC CABLE - 100% NEUTRAL, COPPER CONDUCTOR IN EPR INSULATION

Size #	d_c $[in]$	GMR_c $[in]$	r_c $[\Omega/kft]$	d_{oi} $[in]$	T $[in]$	ϵ_r	d_n $[in]$	GMR_n $[in]$	r_n $[\Omega/kft]$	k	d_{oc} $[in]$	$Ampacity$ $[A]$
1/0	0.373	0.141	0.10020	1.10	0.345	3	0.0808	0.0315	1.588	16	1.53	212
2/0	0.419	0.159	0.07949	1.15	0.345	3	0.1019	0.0397	0.999	13	1.62	245
3/0	0.470	0.178	0.06304	1.20	0.345	3	0.1019	0.0397	0.999	16	1.67	276
4/0	0.528	0.200	0.04999	1.25	0.345	3	0.1019	0.0397	0.999	16	1.81	309
250	0.575	0.221	0.04231	1.31	0.345	3	0.1019	0.0397	0.999	25	1.84	336
350	0.681	0.261	0.03022	1.41	0.345	3	0.1285	0.0501	0.628	22	2.00	398
500	0.813	0.313	0.02116	1.54	0.345	3	0.1285	0.0501	0.628	31	2.16	476

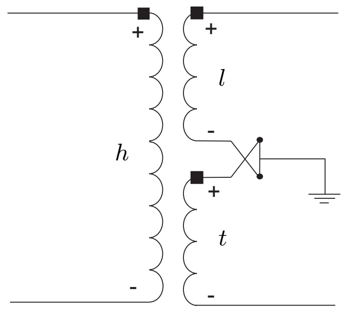

Figure 2. Single phase three winding transformer

IV. MV/LV TRANSFORMERS

Centered-tapped single phase transformers are used to serve single phase (split-phase) residential and small commercial customers. Generally, these transformers have one MV winding (denoted by h) and two LV windings (denoted by l and t), as depicted in Fig. 2. Based on this connection it is possible to obtain $240\ V$ (resp. $480\ V$) between phase conductors or $120\ V$ (resp. $240\ V$) from any phase conductor and the grounded neutral conductor.

In practice, only the nameplate impedance magnitude of the single phase transformer is known, in percent. The latter is the impedance seen from the primary when the full secondary winding is shorted. Table VIII presents the typical parameters of two winding single phase transformers. These parameters are valid for transformers whose primary voltages are: a) $13.2Y/7.62$ and $13.8Y/7.97\ kV$ b) $24.9Y/14.38\ kV$ and $34.5Y/19.92\ kV$ and secondary voltage of $240\ V$ [16]. Due to space limitations, transformers with other primary and secondary voltages are not shown. However, the authors have provided an extended version of this database in [14].

The transformer ratings listed in Table VIII are based on the IEEE Std. C57.12.00-2000 [17]. Some parameters had to be estimated or interpolated with the available data for other capacities. Here, R and X are the real and imaginary components of the full-winding impedance. In addition, P_{oc} and I_{exc} are the no-load transformer losses and excitation current, respectively. All values are in percent based upon the transformer rating.

In order to model single phase three winding transformers, it is necessary to know each winding impedance, denoted as Z_h, Z_l and Z_t. For interlaced secondary windings, as most DN transformers are, it is possible to estimate each winding impedance in terms of the full-winding impedance [10], [15]:

$$\begin{bmatrix} Z_h \\ Z_l \\ Z_t \end{bmatrix} = \begin{bmatrix} 0.5R + j0.8X \\ R + j0.4X \\ R + j0.4X \end{bmatrix} \tag{3}$$

In the case of non-interlaced secondary design, the winding impedances are approximated as:

$$\begin{bmatrix} Z_h \\ Z_l \\ Z_t \end{bmatrix} = \begin{bmatrix} 0.25R - j0.6X \\ 1.5R + j3.3X \\ 1.5R + j3.1X \end{bmatrix} \tag{4}$$

In non-interlaced secondary windings, the impedance to the inner low-voltage winding is less than the impedance to the outer winding [15]. Aditionally, the impedances of non-interlaced secondary windings are significantly larger than for interlaced design. To calculate the impedance between any two windings, one simply calculates the sum of both winding impedances in %, hence:

$$\begin{bmatrix} Z_{hl} \\ Z_{ht} \\ Z_{lt} \end{bmatrix} = \begin{bmatrix} Z_h + Z_l \\ Z_h + Z_t \\ Z_l + Z_t \end{bmatrix} \tag{5}$$

Consider the full winding impedance of a $5\ kVA$, $19.92\ kV - 120/240\ V$ single phase transformer $\%Z = 3.20 + j4.10$ as presented in Table VIII. Based on (3) and (5), the impedances of an interlaced secondary winding design transformer is:

$$\begin{bmatrix} Z_{hl} \\ Z_{ht} \\ Z_{lt} \end{bmatrix} = \begin{bmatrix} 4.80 + j4.92 \\ 4.80 + j4.92 \\ 6.40 + j3.28 \end{bmatrix}$$

Table IX presents the typical parameters of three phase transformers. These transformers are generally two winding transformers. Therefore, each reported impedance is actually the impedance between the primary and secondary windings i.e. $\%R = \%R_{hl}$ and $\%X = \%X_{hl}$.

V. SERVICE CABLES

Service cables are used to serve customers at LV level. Generally, they have a short length (few meters long) to connect the customer's energy meter with the LV network. Depending on the construction and number of conductors, these cables are classified as duplex, triplex or quadruplex. The first two are used in single phase (split-phase) LV networks while quadruplex cables are used in three phase LV systems. Duplex cables may be found in old and small houses served at $120\ V$, specially in the rural areas, while triplex cables connect the vast majority of houses and small businesses with the LV network at $120/240\ V$ in Costa Rica.

This paper focuses on triplex cables. Fig. 3 shows the cross section of a triplex. It is made of two insulated aluminium wires and one twisted bare wire [2]. The bare wire, also known as messenger, is used as the grounded neutral conductor (made of ACSR, AAC or AAAC).

Tables X, XI and XII present the typical parameters of triplex cables whose neutral conductors are ACSR, AAC and AAAC, respectively. Each cable code includes the phase conductor diameter, the neutral conductor diameter and the insulation thickness, as depicted in Fig. 3. These parameters are used to model the 3×3 primitive impedance matrix, according to the modified Carson's equations (1) and (2). Keep in mind that shunt capacitance of triplex cables may be neglected, although it can still be estimated as any other overhead line.

Table VIII
TYPICAL SINGLE PHASE TWO-WINDING TRANSFORMER IMPEDANCES. L-L LV VOLTAGE: 240 V

	$13.2Y/7.62$ & $13.8Y/7.97\ kV$				$24.9Y/14.38\ kV$				$34.5Y/19.92\ kV$			
kVA	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$
5	2.30	0.69	0.84	2.40	2.30	0.69	0.84	2.40	3.20	4.10	0.84	2.40
10	1.40	1.28	0.73	1.60	1.40	1.28	0.73	1.60	2.68	4.45	0.73	1.60
15	1.50	0.99	0.56	1.40	1.50	0.99	0.56	1.40	2.42	4.60	0.56	1.40
25	1.30	1.24	0.47	1.30	1.30	1.24	0.47	1.30	2.20	4.71	0.47	1.30
37.5	1.10	1.42	0.44	1.10	1.10	1.42	0.44	1.10	1.92	4.83	0.44	1.10
50	1.10	1.55	0.37	1.00	1.10	1.55	0.37	1.00	1.70	4.91	0.37	1.00
75	1.00	1.50	0.38	1.40	1.00	1.50	0.38	1.40	1.61	4.95	0.38	1.40
100	0.90	1.79	0.36	1.30	0.90	1.79	0.36	1.30	1.50	4.98	0.36	1.30
167	1.00	1.96	0.30	1.00	1.00	1.96	0.30	1.00	1.31	5.03	0.30	1.00
250	1.20	2.64	0.24	1.00	1.20	2.64	0.24	1.00	1.18	5.06	0.24	1.00
333	1.00	2.93	0.25	1.00	1.00	2.93	0.25	1.00	1.10	5.08	0.25	1.00
500	1.10	3.00	0.23	1.00	1.10	3.00	0.23	1.00	1.00	5.10	0.23	1.00

Table IX
TYPICAL THREE PHASE TWO-WINDING TRANSFORMER IMPEDANCES. L-L LV VOLTAGE: 240 V

	$13.2Y/7.62$ & $13.8Y/7.97\ kV$				$24.9Y/14.38\ kV$				$34.5Y/19.92\ kV$			
kVA	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$	$\%R$	$\%X$	$\%P_{oc}$	$\%I_{exc}$
9	2.63	2.84	1.06	2.48	2.63	2.84	1.06	2.48	3.82	3.96	1.06	2.48
30	2.10	2.28	0.71	1.72	2.10	2.28	0.71	1.72	2.68	4.80	0.71	1.72
45	1.74	2.08	0.62	1.52	1.74	2.08	0.62	1.52	2.38	4.96	0.62	1.52
75	1.30	1.65	0.48	1.50	1.30	1.65	0.48	1.50	2.04	5.11	0.48	1.50
112	1.10	1.30	0.47	1.00	1.10	1.30	0.47	1.00	1.88	5.17	0.47	1.00
150	1.10	1.55	0.37	1.00	1.10	1.55	0.37	1.00	1.67	5.24	0.37	1.00
225	1.10	1.55	0.39	1.00	1.10	1.55	0.39	1.00	1.48	5.30	0.39	1.00
300	1.10	1.67	0.35	1.00	1.10	1.67	0.35	1.00	1.40	5.32	0.35	1.00
500	1.00	2.07	0.32	1.00	1.00	2.07	0.32	1.00	1.20	5.37	0.32	1.00
750	1.10	5.59	0.24	1.00	1.10	5.59	0.24	1.00	1.04	5.40	0.24	1.00
1000	1.00	5.61	0.21	1.00	0.91	5.49	0.25	1.42	0.91	5.49	0.25	1.42
1500	1.10	5.59	0.19	1.00	0.80	5.50	0.24	1.37	0.80	5.50	0.24	1.37
2500	1.10	5.59	0.17	1.00	0.72	5.51	0.21	1.31	0.72	5.51	0.21	1.31
3750	1.10	5.59	0.15	1.00	0.69	4.95	0.23	1.33	0.69	4.95	0.23	1.33

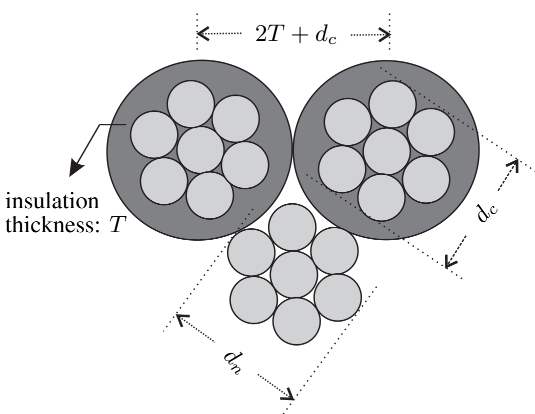

Figure 3. Triplex cable

As an example, consider the *Voluta* triplex cable whose parameters are defined in Table X. When evaluating (1) and (2) for the conductor distances in Fig. 3, and the conductors' resistance in $\Omega/mile$, the 3×3 primitive impedance matrix of this triplex cable is:

$$\begin{bmatrix} 4.3457 + j1.5919 & 0.0953 + j1.4213 & 0.0953 + j1.4394 \\ 0.0953 + j1.4213 & 4.3457 + j1.5919 & 0.0953 + j1.4394 \\ 0.0953 + j1.4394 & 0.0953 + j1.4394 & 4.3510 + j1.5757 \end{bmatrix}$$

Note that the Kron reduction can be applied to the primitive impedance matrix to calculate the 2×2 phase impedance matrix, as explained in [10].

VI. CONCLUSION

This paper has presented a database of typical parameters of conductors, transformers and cables commonly used in the Costa Rican distribution networks. This database gathers information from different manufacturers and reference books,

Table X
TRIPLEX CABLE WITH FULL SIZE ACSR NEUTRAL-MESSENGER

Code	Size # $[AWG]$	d_c $[in]$	GMR_c $[ft]$	r_c $[\Omega/kft]$	T $[mils]$	d_n $[in]$	GMR_n $[ft]$	r_n $[\Omega/kft]$	$Ampacity$ $[A]$
Voluta	6	0.184	0.0056	0.8050	45	0.198	0.0064	0.806	70
Periwinkle	4	0.232	0.0070	0.5060	45	0.250	0.0080	0.515	90
Conch	2	0.292	0.0088	0.3180	45	0.316	0.0101	0.332	120
Neritina	1/0	0.368	0.0111	0.2000	60	0.398	0.0127	0.217	160
Runcina	2/0	0.414	0.0125	0.1590	60	0.447	0.0143	0.176	185
Mursia	3/0	0.464	0.0140	0.1260	60	0.502	0.0161	0.144	215
Zuzara	4/0	0.522	0.0158	0.0999	60	0.563	0.0180	0.119	245

Table XI
TRIPLEX CABLE WITH FULL SIZE AAC NEUTRAL-MESSENGER

Code	Size # $[AWG]$	d_c $[in]$	GMR_c $[ft]$	r_c $[\Omega/kft]$	T $[mils]$	d_n $[in]$	GMR_n $[ft]$	r_n $[\Omega/kft]$	$Ampacity$ $[A]$
Patella	6	0.184	0.0056	0.8050	45	0.184	0.0056	0.8050	70
Oyster	4	0.232	0.0070	0.5060	45	0.232	0.0070	0.5060	90
Clam	2	0.292	0.0088	0.3180	45	0.292	0.0088	0.3180	120
Murex	1/0	0.368	0.0111	0.2000	60	0.368	0.0111	0.2000	160
Nassa	2/0	0.414	0.0125	0.1590	60	0.414	0.0125	0.1590	185
Melita	3/0	0.464	0.0140	0.1260	60	0.464	0.0140	0.1260	215
Portunus	4/0	0.522	0.0158	0.0999	60	0.522	0.0158	0.0999	245

Table XII
TRIPLEX CABLE WITH FULL SIZE AAAC NEUTRAL-MESSENGER

Code	Size # $[AWG]$	d_c $[in]$	GMR_c $[ft]$	r_c $[\Omega/kft]$	T $[mils]$	d_n $[in]$	GMR_n $[ft]$	r_n $[\Omega/kft]$	$Ampacity$ $[A]$
Hippa	6	0.184	0.0056	0.8050	45	0.198	0.0060	0.7850	70
Barnacle	4	0.232	0.0070	0.5060	45	0.250	0.0075	0.4930	90
Shrimp	2	0.292	0.0088	0.3180	45	0.316	0.0095	0.3100	120
Gammarus	1/0	0.368	0.0111	0.2000	60	0.398	0.0120	0.1950	160
Dungenese	2/0	0.414	0.0125	0.1590	60	0.447	0.0134	0.1540	185
Flustra	3/0	0.464	0.0140	0.1260	60	0.502	0.0151	0.1230	215
Lepas	4/0	0.522	0.0158	0.0999	60	0.563	0.0169	0.0973	245

and it is intended to be consulted by power engineers working on accurate models of distribution networks.

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