ELECTRICITY NORTH WEST LIMITED

LV Capacitor Placement Study

PHASE 1 – CAPACITOR PLACEMENT AND SIZING

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1. INTRODUCTION

This report summarises the results and findings of LV capacitor bank placement and sizing studies undertaken by S&C Electric Europe Ltd (S&C) on a set of Electricity Northwest Limited (ENW) network feeders described in Table 1.

In addition, the report summarises the considered study assumptions, methodology, results, conclusions, and presents any recommendations drawn from the undertaken studies.

Table 1 – LV Capacitor Placement and Sizing Study Feeders

No#	Secondary Substation			
	Substation Name	Substation No.	Location	Feeder Feature No.
1	Greenside Lane	171747	Manchester	527400008
2	Edge Green Lane	216438	Wigan	66074753
3	Howard Street	166559	Salford	216044696
4	Landgate	211951	Wigan	63057172
5	Leicester Avenue	212726	Wigan	69051565
6	Dunton Green	330127	Stockport	260055770

Note: Feeders with feature numbers 69051565 and 260055770 in Table 1 were selected by S&C based on the feeder voltage profile assessment studies, while the information on the remainder of the feeders to be studied was provided by ENW.

2. NETWORK DATA, ASSUMPTIONS AND MODELLING

Four wire models of the LV networks (Table 1) were developed in PowerFactory software based on the supplied node, feeder, load, and Photovoltaic (PV) generation data provided by the University of Manchester.

Principle network data is briefly summarised in Appendix C, while the Geographical Information System (GIS) layout diagrams of the modelled networks are given in Appendix B.

The following modelling assumptions were considered:

- The customer loads connected to the study feeders in Table 1 were scaled such that the total secondary transformer load and feeder load do not exceed 100% and 80% respectively. The identified customer loads per phase based on this methodology is given in Table 2 and were used in the study.
    - In addition, a set of three study feeder loading scenarios that are a representative proportion of the total transformer loading when supplying all connecting feeders were considered. The three feeder loading scenarios were selected as following: high - 90%, medium - 60%, and low - 30%. These load scaling factors were then applied to all domestic and commercial customer loads.
    - Similarly for feeder with PV generation name plate information made available (Dunton Green substation only), the following generation scaling factors were selected: high - 100%, medium - 50%, and low – 0%. These load scaling factors were then applied to all PV generators connected to the study feeder.
- Load phase connection information was adopted from Mapinfo data[1] of ENW LV network. Where load phase information was not available, a balanced load distribution among three phases was considered.
- Where feeder termination earthing notations were indicated in Mapinfo data, these terminations were modelled as solid ground systems.
- Furthermore, it was assumed that the substation LV terminal voltages will be maintained within ±3% of 230V nominal, accounting for loading on all LV feeders connected to each substation. Accordingly, a set of two extreme voltage levels were considered at the substation LV terminals (0.97p.u representing low supply volts, and 1.03p.u for high) and studied.

[1] Provided by ENW to S&C via DVD labelled 'MapInfo ProViewer Dataset', issued on the 19th Feb 2013.

Table 2 – Considered Feeder Load

No#	Secondary Substation			Customer Load per Phase (kW)
	Substation Name	Substation No.	Feeder Feature No.	
1	Greenside Lane	171747	527400008	1.33
2	Edge Green Lane	216438	66074753	0.92
3	Howard Street	166559	216044696	1.62
4	Landgate	211951	63057172	1.62
5	Leicester Avenue	212726	69051565	1.75
6	Dunton Green	330127	260055770	1.19

3. CAPACITOR PLACEMENT AND SIZING METHODOLOGY

- Spot checks on the modelled network were made to check for data consistency - feeder continuity, feeder cable types, load phase connections, etc.
- Based on the considered substation LV voltage extremes and LV feeder loading and connected PV generation levels, the following scenarios were considered.
  - Scenario A1 – low supply volts, low load, high generation
  - Scenario A2 – low supply volts, medium load, medium generation
  - Scenario A3 – low supply volts, high load, no generation
  - Scenario B1 – high supply volts, low load, high generation
  - Scenario B2 – high supply volts, medium load, medium generation
  - Scenario B3 – high supply volts, high load, no generation
- All feeders, except for the feeder under study, were maintained de-energised. The feeders for Leicester Avenue and Dunton Green substations in Table 2 were selected based on the worst case voltage drops (voltage profile assessment studies) seen among all connected feeders at these substations.
- For each case study (scenarios A1 to B3) with no LV capacitors installed, load flow calculations were undertaken with LV substation voltages maintained as per selected study scenario description, and relevant voltage profiles and load flow voltage sensitivity factors were obtained.
- Obtained results were analysed and appropriate locations for capacitor installations - with a maximum of two capacitor banks per feeder - were identified along the feeder.
- Switchable voltage regulating three-phase delta connected LV capacitor banks with a maximum of 20 steps (only used for capacitor size identifying purposes and does not represent the final capacitor size or steps needed) with 50kVAr/step were connected at identified capacitor placement locations. As a default, a target voltage regulation range of ±5% of 230V nominal value was used on all modelled capacitors.
- For each of the case studies Case A1 to B3 with LV capacitors installed, load flow calculations were undertaken incorporating automatic shunt step adjustment. The resultant new voltage profiles and calculated capacitor step results were obtained and tabulated.
- Based on the minimum capacitor step adjustments at modelled locations during load flow calculations, a suitable capacitor size was selected.

4. RESULTS AND DISCUSSION

This section summarises principle results and findings observed from the undertaken load flow based capacitor sizing and placement studies.

4.1.1. Performance with No Capacitor Regulation

Feeder voltage profile analysis was undertaken on base networks (summarised in Table 1) with no capacitors installed. Principal results from these studies are tabulated in Table 3 and corresponding voltage profile plots are given in Appendix D.

For each study feeder and corresponding connected substation, only the highlighted scenarios (column Case# in red text) in Table 3 were found to exceed the LV statutory limits of 0.94p.u and 1.1p.u of 230V nominal voltage. These highlighted scenarios are feeders accounting for medium and high level of loading conditions. The voltage profiles for all other cases (in Table 3), not highlighted in red text, were found to be within LV statutory limits.

Table 3 – Voltage Profile and Feeder Loading Results with No Capacitor Regulation

Substation Name	Feeder Feature No.	Case#	Sub. Vol. Set Point (p.u)	Feeder Vol. Drop Range (p.u)	Max. Feeder Loading (%)
Greenside Lane	527400008	A1	0.97	0.95 to 0.97	29.7
		A2	0.97	0.94 to 0.97	58.6
		A3	0.97	0.92 to 0.97	89.2
		B1	1.03	1.01 to 1.03	28.0
		B2	1.03	1.00 to 1.03	55.0
		B3	1.03	0.98 to 1.03	83.6
Edge Green Lane	66074753	A1	0.97	0.96 to 0.97	30.3
		A2	0.97	0.95 to 0.97	53.1
		A3	0.97	0.94 to 0.97	80.6
		B1	1.03	1.02 to 1.03	28.5
		B2	1.03	1.01 to 1.03	49.9
		B3	1.03	1.00 to 1.03	75.6

Substation Name	Feeder Feature No.	Case#	Sub. Vol. Set Point (p.u)	Feeder Vol. Drop Range (p.u)	Max. Feeder Loading (%)
Howard Street	216044696	A1	0.97	0.96 to 0.97	26.9
		A2	0.97	0.95 to 0.97	53.0
		A3	0.97	0.94 to 0.97	80.1
		B1	1.03	1.02 to 1.03	25.3
		B2	1.03	1.01 to 1.03	49.8
		B3	1.03	1.01 to 1.03	75.2
Landgate	63057172	A1	0.97	0.95 to 0.97	30.0
		A2	0.97	0.92 to 0.97	56.6
		A3	0.97	0.90 to 0.97	86.6
		B1	1.03	1.01 to 1.03	28.1
		B2	1.03	0.99 to 1.03	53.1
		B3	1.03	0.96 to 1.03	81.0
Leicester Avenue	69051565	A1	0.97	0.95 to 0.97	30.1
		A2	0.97	0.93 to 0.97	58.5
		A3	0.97	0.90 to 0.97	89.2
		B1	1.03	1.01 to 1.03	28.3
		B2	1.03	0.99 to 1.03	54.9
		B3	1.03	0.97 to 1.03	83.5
Dunton Green	260055770	A1	0.97	0.95 to 1.00	103.2
		A2	0.97	0.93 to 0.98	50.8
		A3	0.97	0.90 to 0.97	93.9
		B1	1.03	1.01 to 1.06	102.8
		B2	1.03	1.00 to 1.04	50.7
		B3	1.03	0.97 to 1.03	87.8

The high Dunton Green feeder loading in cases A1 and B1 was due to consideration of PV generation.

4.1.2. Performance with Capacitor Regulation – Capacitor Placement and Sizing

For the identified scenarios (A1 to B3) with severe voltage deviations (only A2 and A3) at each study substation and feeder in Section 4.1.1, capacitor regulation solution was considered. The capacitor sizes and their location along each study feeder were calculated according to the methodology in Section 3.

Table 4 summarises a list of problem cases for each study feeder (results reproduced from Section 4.1.1) and required minimum capacitor bank sizes and installation locations to improve feeder voltages. The locations of these identified capacitors are mark on the GIS network model diagrams given in Appendix B.

Table 5 summarises the impact of the calculated capacitor banks and locations in Table 4 on corresponding feeder voltage profiles and loading.

Table 4 – Calculated Capacitor Sizes to Improve Feeder Voltages

Sub. Name	Feeder Feature No.	Case#	Problem	Calculated Cap. Sizes	
			Feeder Vol. Drop Range (p.u) - With No Capacitor Regulation	Capacitor Installation Size (kVAr)	Installation Distance from Sub. (m)
Greenside Lane	527400008	A2	0.94 to 0.97	100	200
		A3	0.92 to 0.97	200	200
Edge Green Lane	66074753	A3	0.94 to 0.97	100	100
Howard Street	216044696	A3	0.94 to 0.97	100	100
Landgate	63057172	A2	0.92 to 0.97	150	200
		A3	0.90 to 0.97	250	200
Leicester Avenue	69051565	A2	0.93 to 0.97	150	100
		A3	0.90 to 0.97	250	100
Dunton Green	260055770	A2	0.93 to 0.98	100	100
		A3	0.90 to 0.97	450	100

Table 5 – Impact of Table 4 Capacitors on Feeder Vol. Profiles, Loading, and Vol. Step Change

Sub. Name	Feeder Feature No.	Case#	Sub. Vol. Set Point (p.u)	Problem	Resultant Feeder Performance with Calculated Capacitors		
				Feeder Vol. Drop Range (p.u) - With No Capacitor Regulation	Feeder Vol. Drop Range (p.u)	Max. Feeder Loading (%)	Max. Feeder Vol. Step Change (%)
Greenside Lane	527400008	A2	0.97	0.94 to 0.97	0.95 to 0.98	59.1	1.5
		A3	0.97	0.92 to 0.97	0.95 to 0.98	98.2	3.2
Edge Green Lane	66074753	A3	0.97	0.94 to 0.97	0.95 to 0.98	79.5	1.5
Howard Street	216044696	A3	0.97	0.94 to 0.97	0.95 to 0.98	82.0	0.9
Landgate	63057172	A2	0.97	0.92 to 0.97	0.95 to 0.98	73.3	2.9
		A3	0.97	0.90 to 0.97	0.94 to 0.99	OL[2]	5.1
Leicester Avenue	69051565	A2	0.97	0.93 to 0.97	0.95 to 0.99	75.4	2.4
		A3	0.97	0.90 to 0.97	0.94 to 1.00	OL	4.2
Dunton Green	260055770	A2	0.97	0.93 to 0.98	0.94 to 0.99	76.1	1.1
		A3	0.97	0.90 to 0.97	0.94 to 1.00	OL	4.6

The following findings were drawn from the undertaken capacitor placement and sizing analysis, results presented in Table 4, Table 5, and voltage profiles (comparison with and without Table 4 capacitors for each case) given in Appendix A, and input received from ENW:

- The number of capacitor banks per feeder was principally based on the required voltage improvement and feeder thermal limits.

[2] Overload (OL) conditions exceeding feeder thermal ratings, which have to be investigated further.

  - Irrespective of separate individual block units considered on each study feeder, the required minimum total capacitor banks capacitance value did not change. Therefore, the impact of a single lumped capacitor or its distribution in smaller modular units towards the substation on the feeder loading remained the same.

- For most medium loading conditions among all considered feeders, a minimum capacitor size of approximately 100kVAr to 150kVAr would sufficiently maintain LV voltage within statutory limits. In addition, the following features were identified for the same feeder loading condition:
  - The identified minimum capacitors can be connected at approximately 100m to 200m along each feeder to provide adequate voltage regulation and maintain feeder currents within thermal limits.
  - The voltage step change due to identified capacitor sizes are expected to be within 3%, which are likely to be within voltage step change tolerances of most LV connected equipment.

- For considered maximum feeder loading scenarios (except for study feeders at Edge Green Lane and Howard Street substations), large capacitor banks with minimum sizes from 200 to 450kVAr may be required to regulate feeder voltages within statutory limits and their installation at any point along their corresponding feeder is likely to cause a feeder overloading problem.
  - In addition, the voltage step changes due to switching of identified capacitor sizes under maximum feeder loading conditions is likely to exceed 3%.

- It is understood that for most feeders in ENW network[3], the likely loading is around 30% to 60%. Among the considered feeder loading scenarios, this ranges from a low to medium loading condition. Therefore, the feeder medium loading scenario is likely to be more realistic, yet the identified capacitor sizes are based on a conservative voltage considered at the substation (pre-regulation voltage set point of 0.97p.u).
  - Accordingly, the capacitor placement and sizing results for all study feeders, except for study feeders at Edge Green Lane and Howard Street substations, were based on medium loading results, while the capacitor placement and sizing results for study feeders at Edge Green Lane and Howard Street substations were based on the maximum loading results.

[3] ENW Gavin Anderson's input via John Simpson forwarded to S&C on the 18th Mar 2013.

5. CONCLUSIONS AND RECOMMENDATIONS

The capacitor placement and sizing study has identified a requirement for installation of LV capacitor banks on each study feeder to enable LV feeder voltages to be within statutory limits.

Table 6 summarises the recommended capacitor bank size and its placement (locations marked on the GIS network layout diagrams in Appendix B) along each provided and selected study feeder.

Table 6 – Recommended Feeder Capacitor Bank Sizes and Placement

Substation Name	Feeder Feature No.	Feeder Vol. Drop Range (p.u) With No Capacitor Regulation	Recommended Capacitor Installations		Expected Improved Feeder Vol. Drop Range (p.u) With Capacitor Regulation
			Capacitor Installation Size (kVAr)	Installation Distance from Sub. (m)	
Greenside Lane	527400008	0.94 to 0.97	100	200	0.95 to 0.98
Edge Green Lane	66074753	0.94 to 0.97	100	100	0.95 to 0.98
Howard Street	216044696	0.94 to 0.97	100	100	0.95 to 0.98
Landgate	63057172	0.92 to 0.97	150	200	0.95 to 0.98
Leicester Avenue	69051565	0.93 to 0.97	150	100	0.95 to 0.98
Dunton Green	260055770	0.93 to 0.98	100	100	0.94 to 0.99

Appendix A. FEEDER VOLTAGE PROFILES - WITH CAPACITORS

Results below are study feeder load scenarios with statutory voltage violations and improvement with installation of calculated capacitors in Table 4.

<u>Green Side Lane</u>:

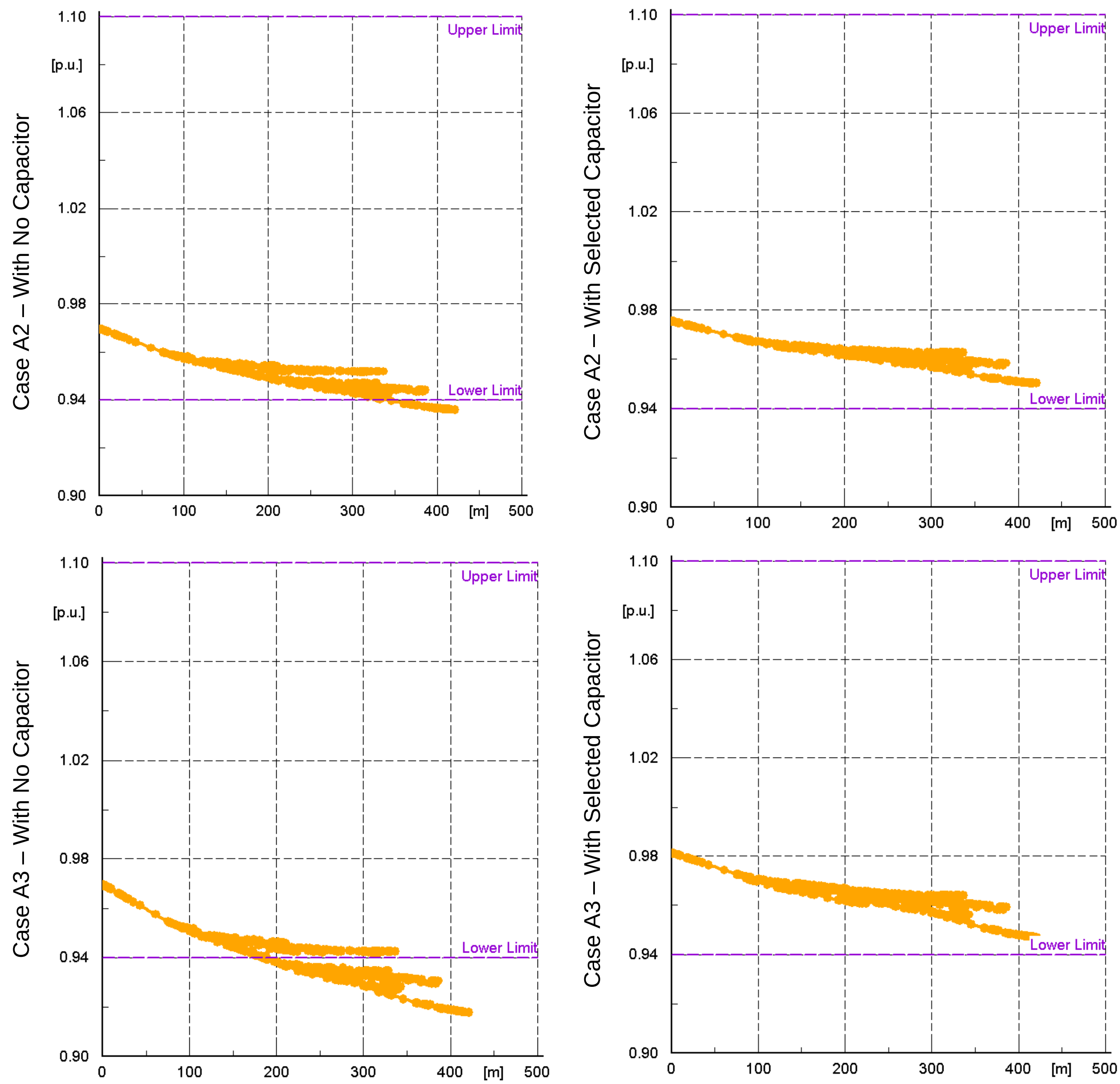

Figure A1 – Feeder#527400008 Voltage Profiles with and without Capacitors (Cases A2 and A3)

Edge Green Lane:

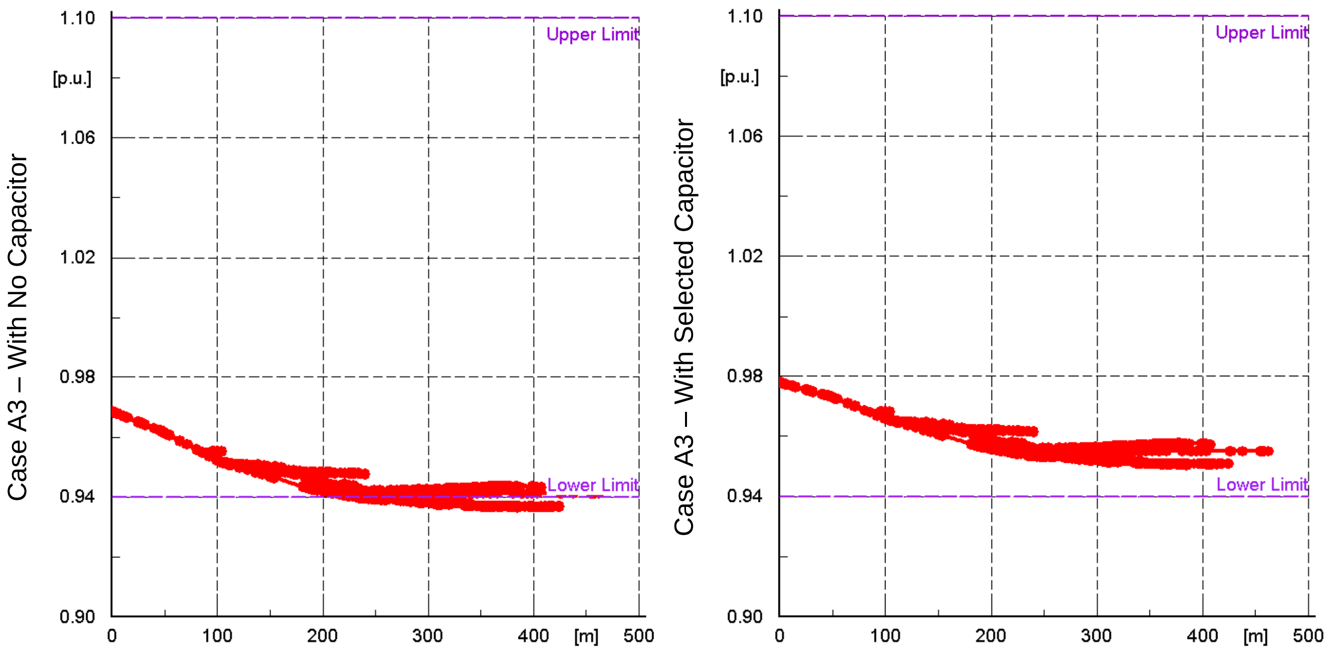

Figure A2 – Feeder#66074753 Voltage Profiles with and without Capacitors (Case A3)

Howard Street:

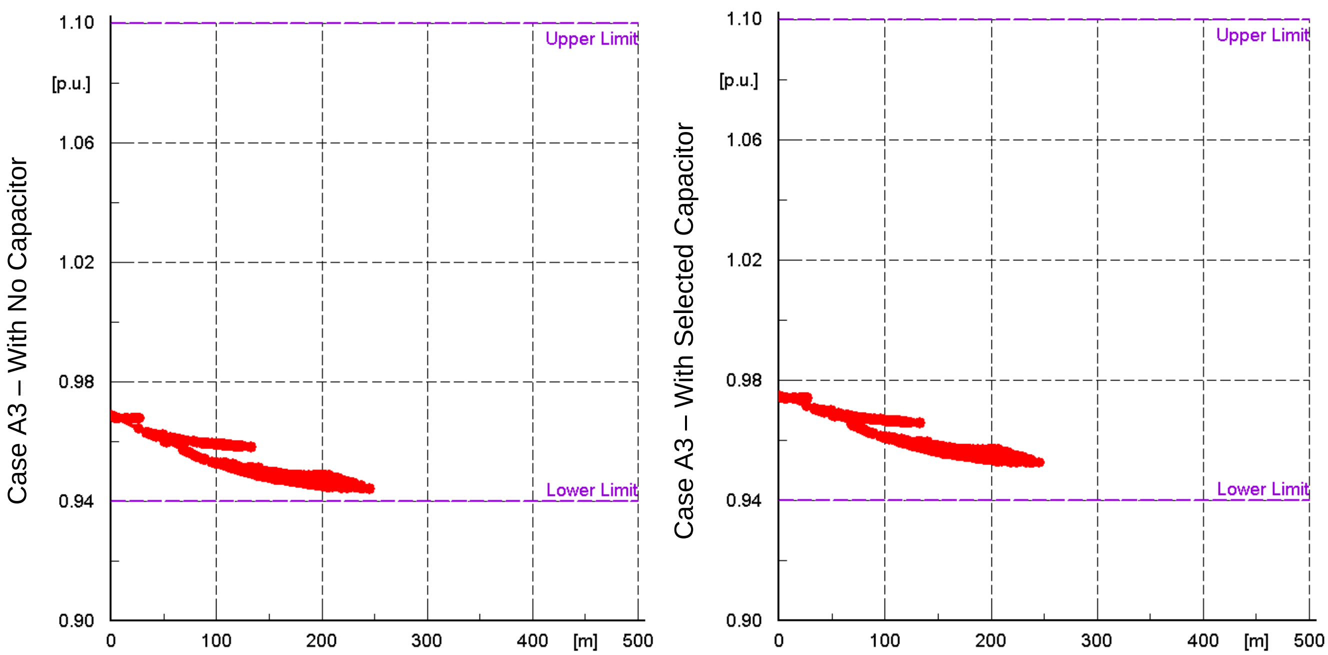

Figure A3 – Feeder#216044696 Voltage Profiles with and without Capacitors (Case A3)

Landgate:

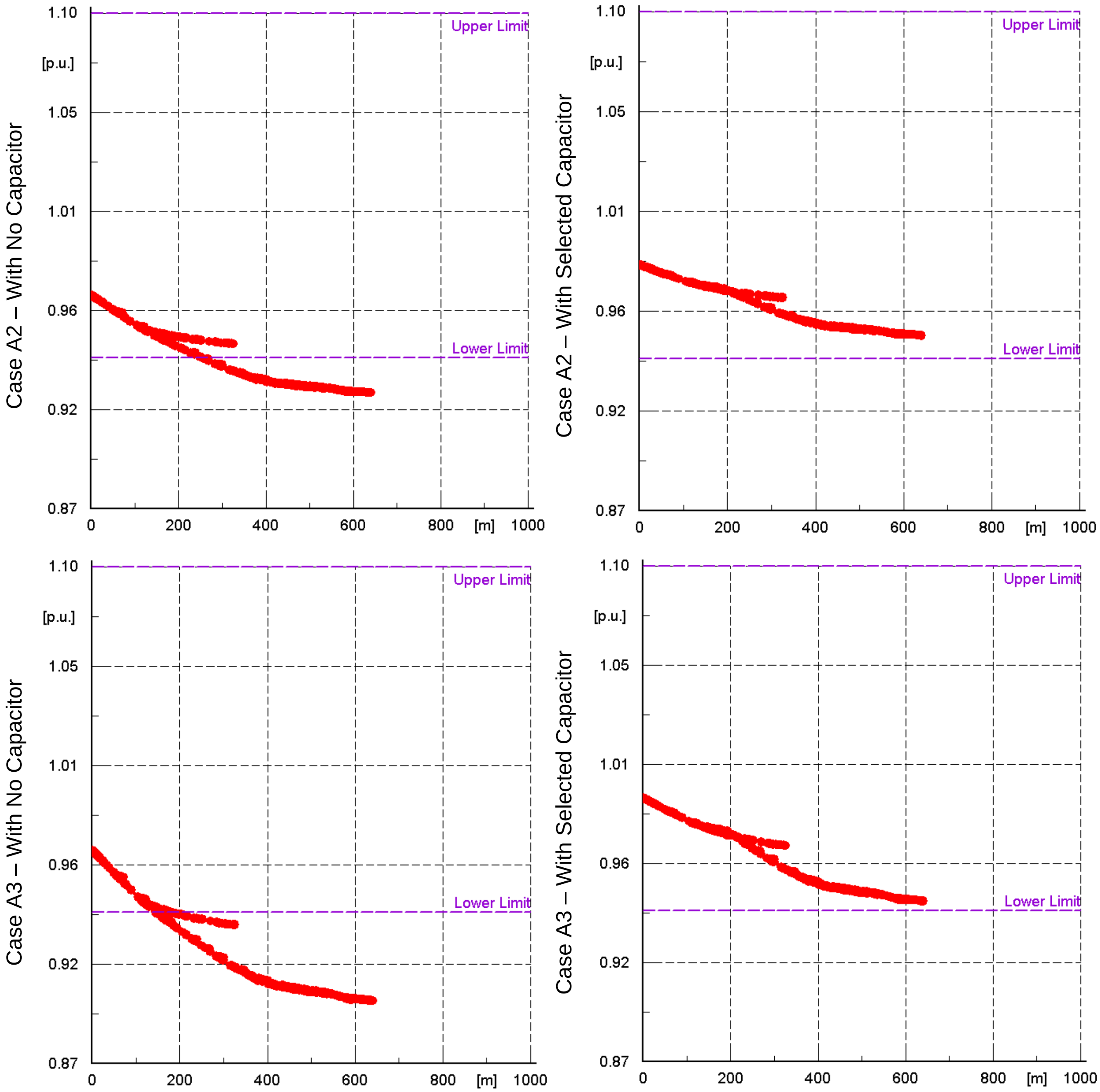

Figure A4 – Feeder#63057172 Voltage Profiles with and without Capacitors (Cases A2 and A3)

Leicester Avenue:

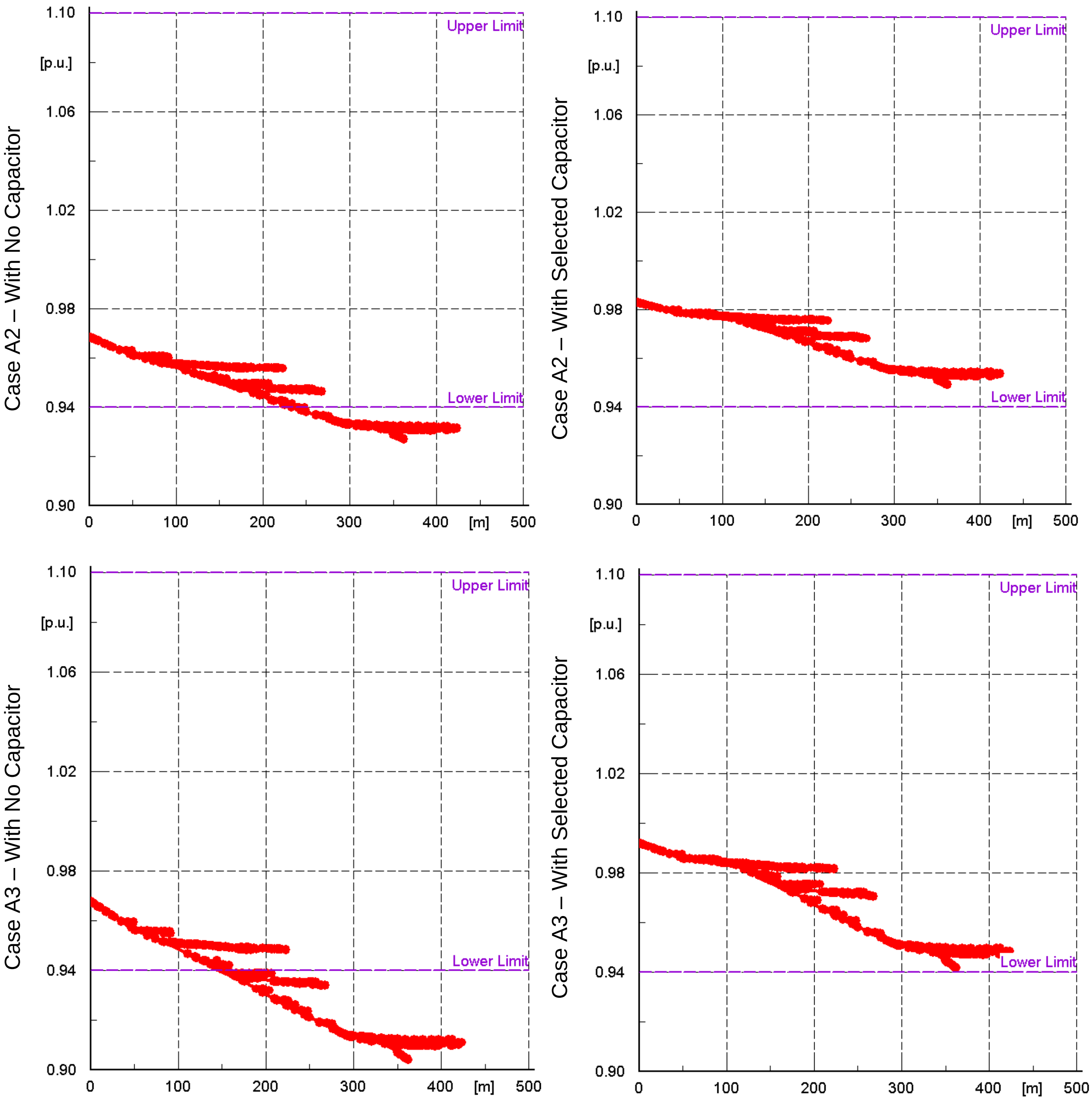

Figure A5 – Feeder# 69051565 Voltage Profiles without Capacitors (Cases A2 and A3)

Dunton Green:

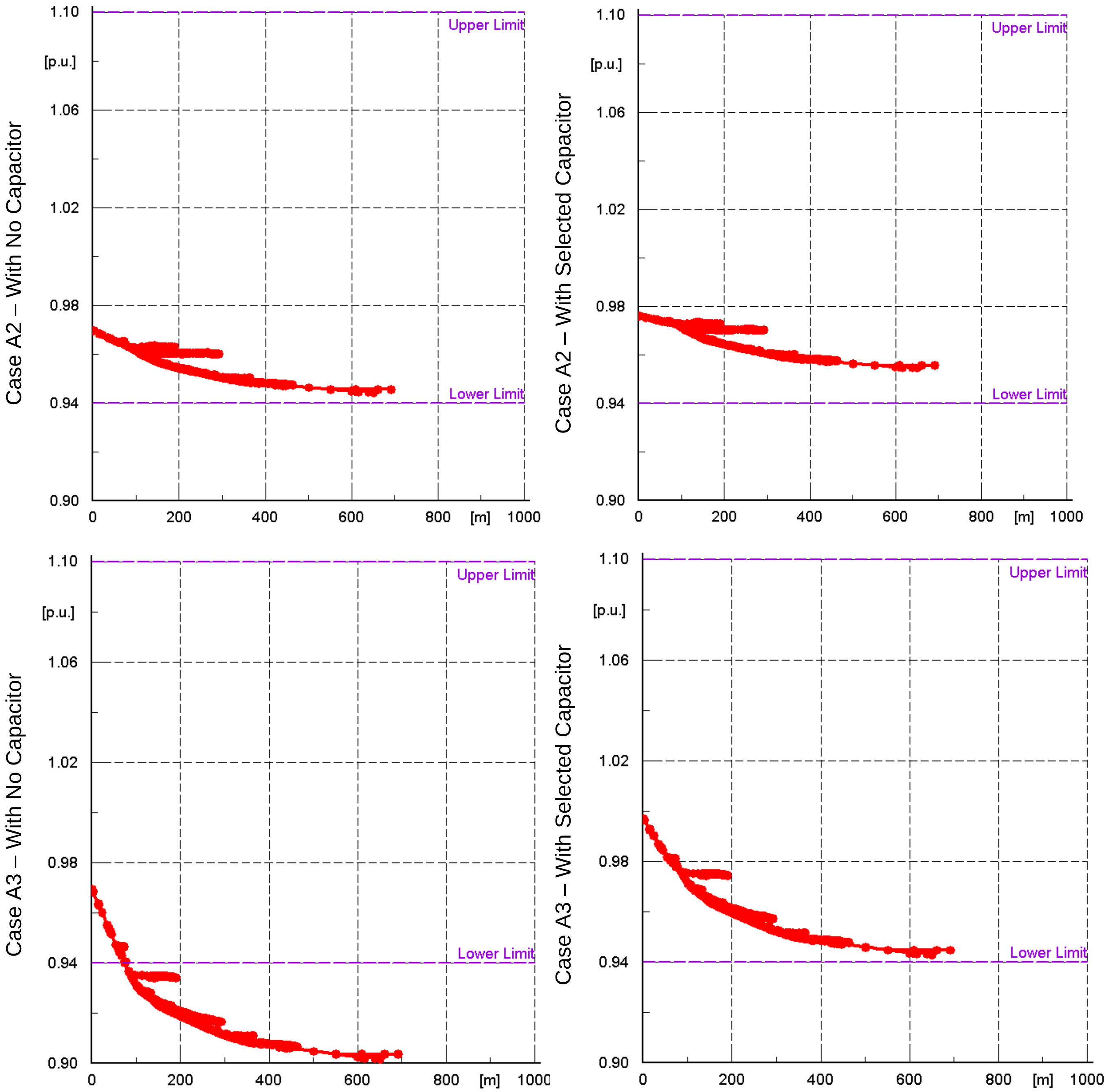

Figure A6 – Feeder# 260055770 Voltage Profiles without Capacitors (Cases A2 and A3)

Appendix B. GIS NETWORK DIAGRAMS – WITH CAPACITORS

Study feeder substation GIS network model layouts with Table 6 capacitor placements marked.

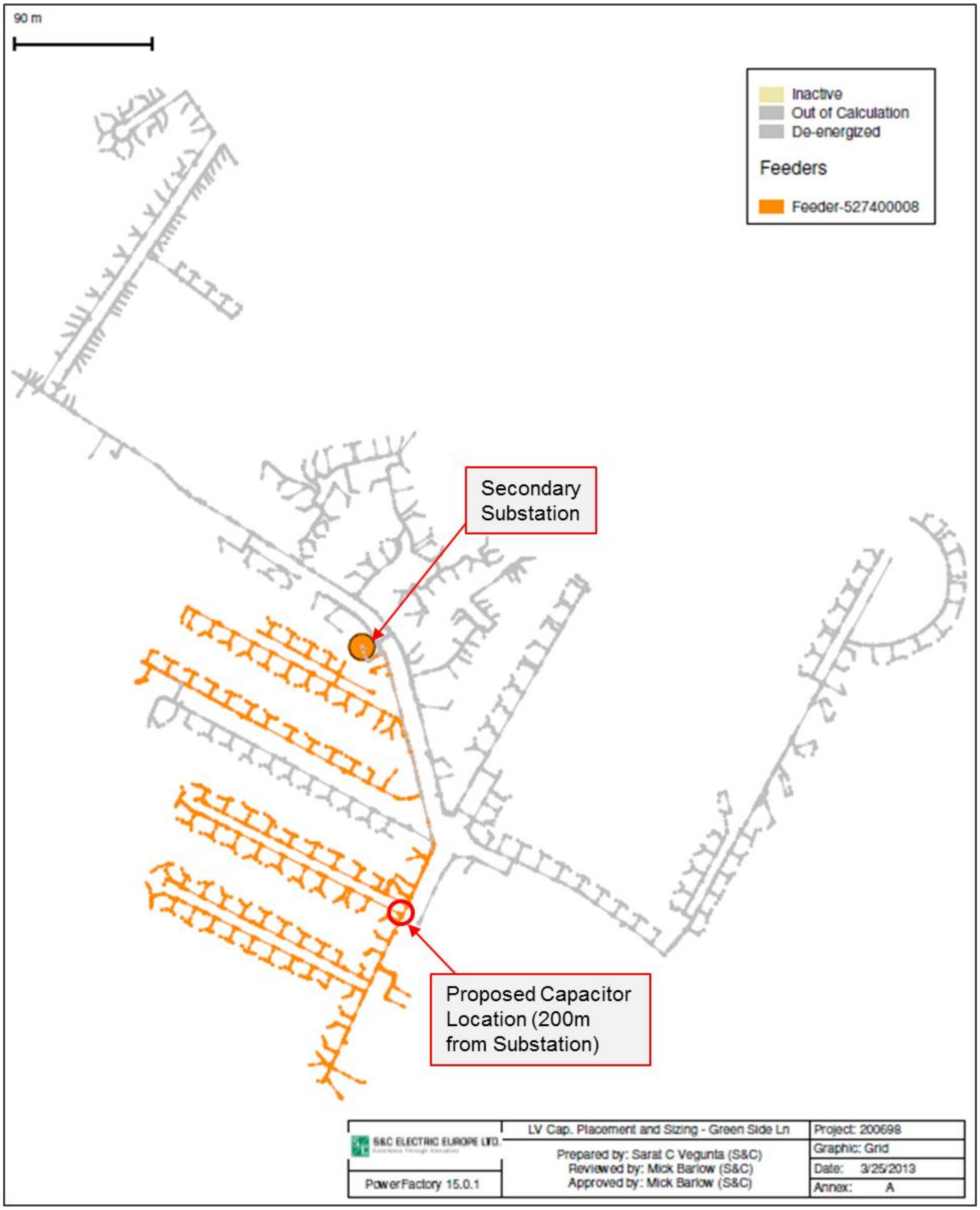

Figure B1 – Green Side Ln Fiveways LV Network

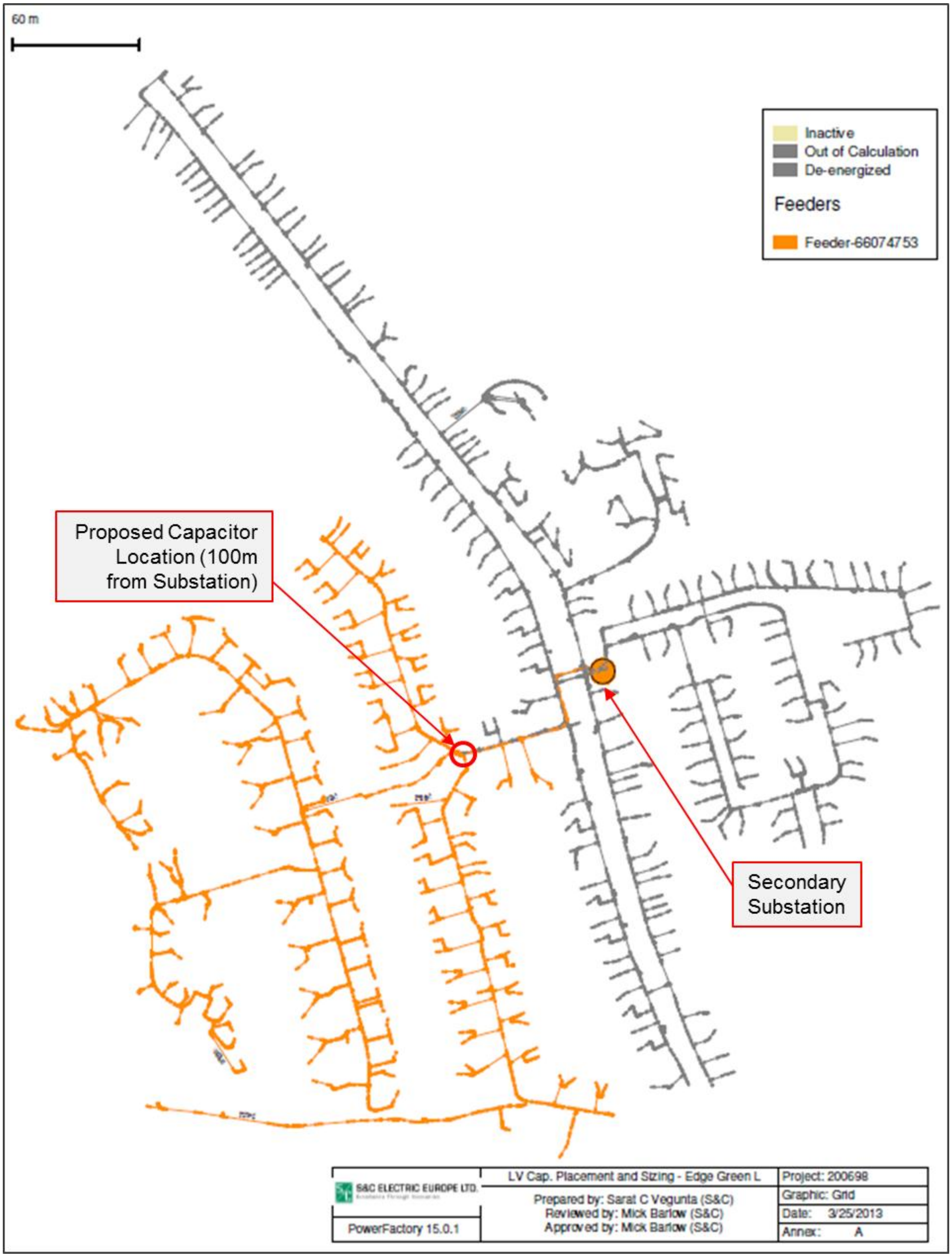

Figure B2 – Edge Green Ln LV Network

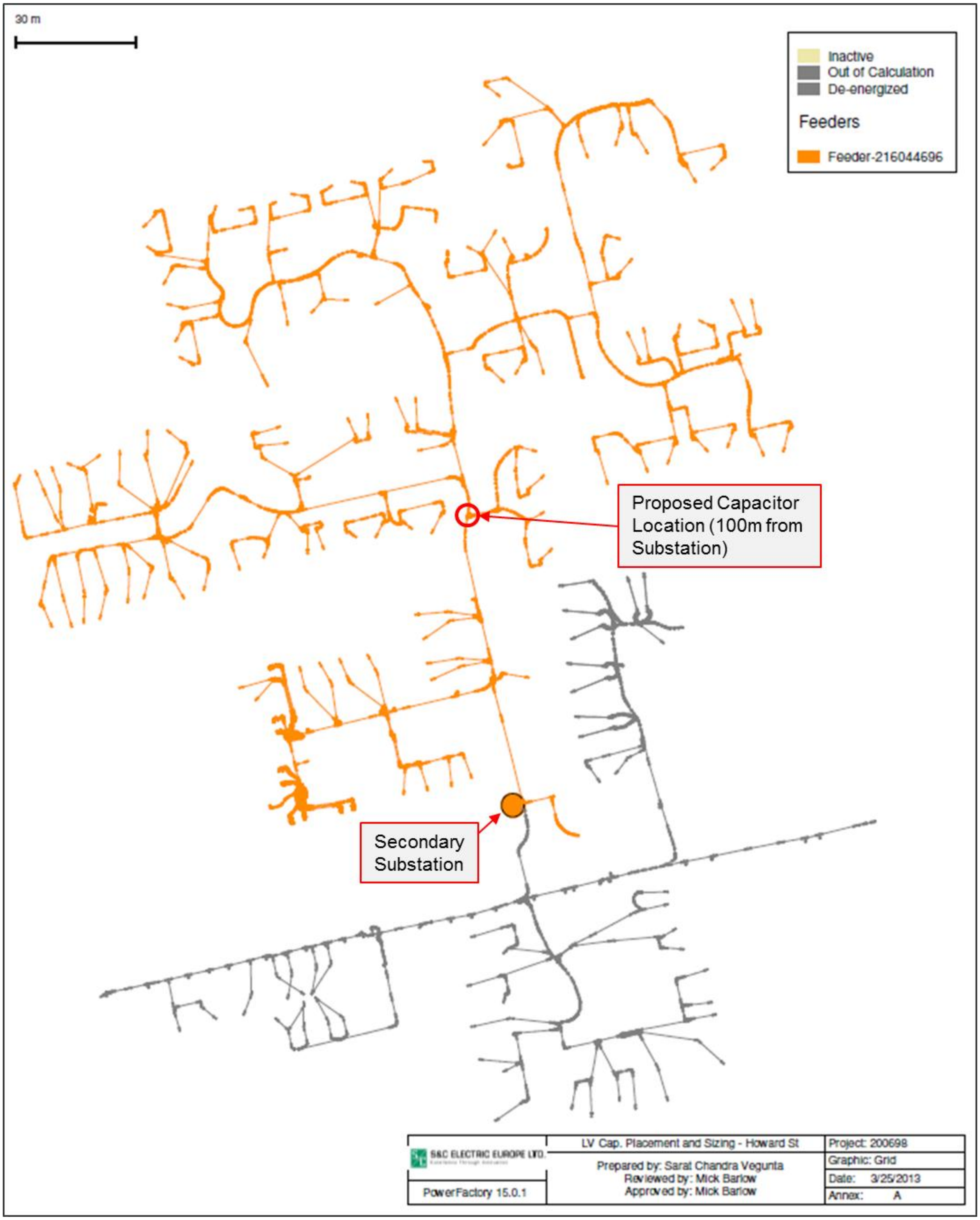

Figure B37 – Howard St LV Network

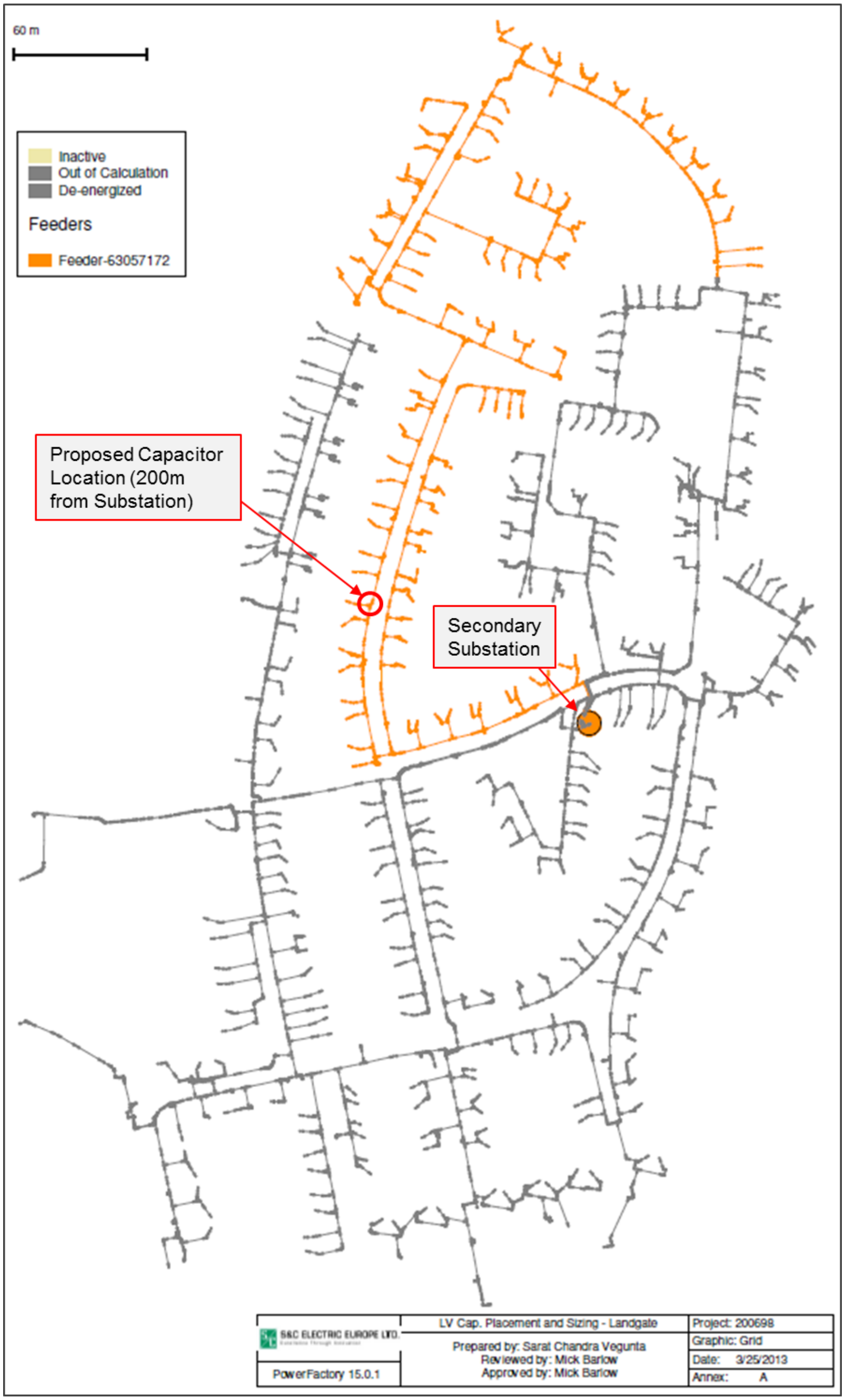

Figure B4 – Landgate LV Network

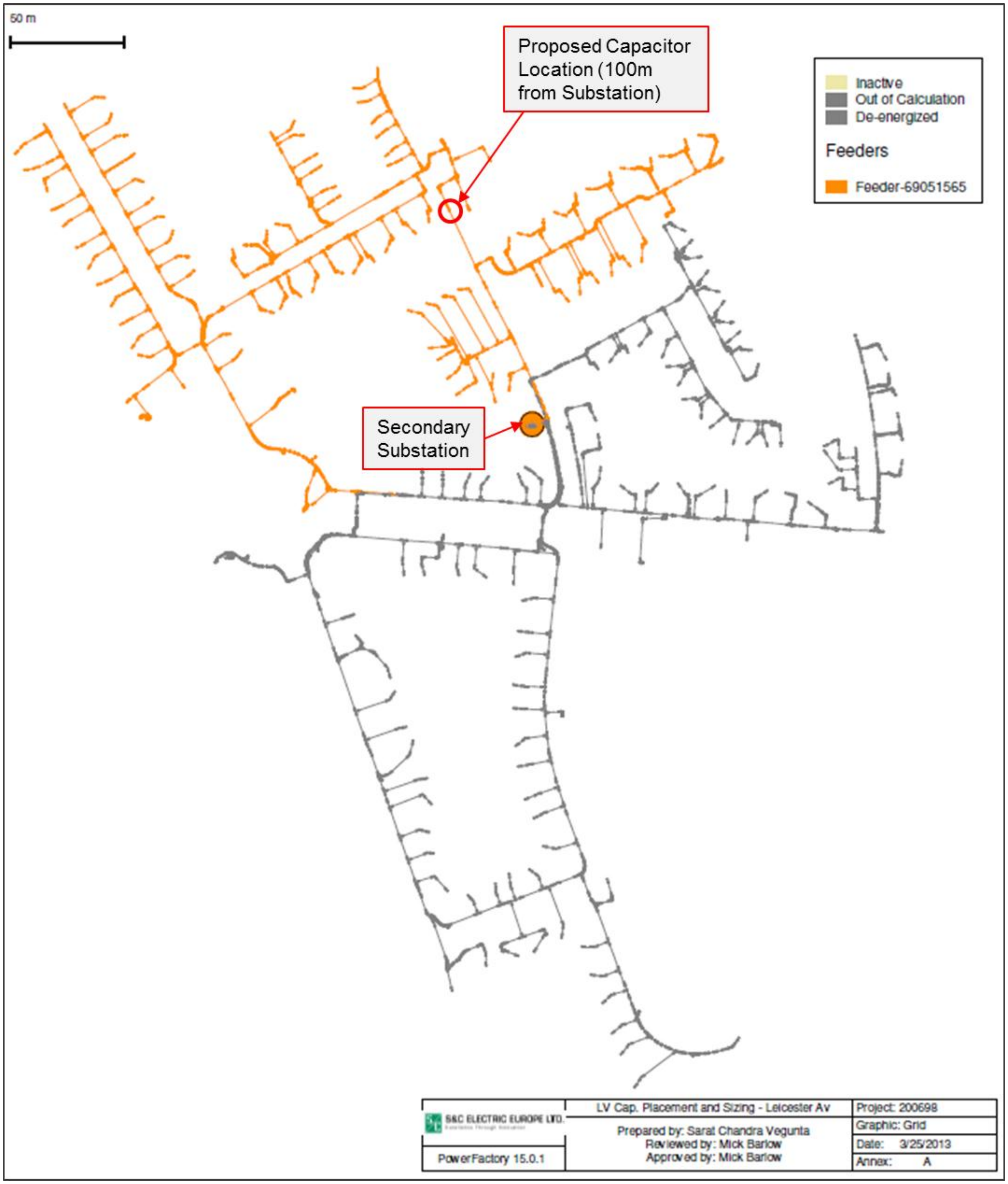

Figure B5 – Leicester Av LV Network

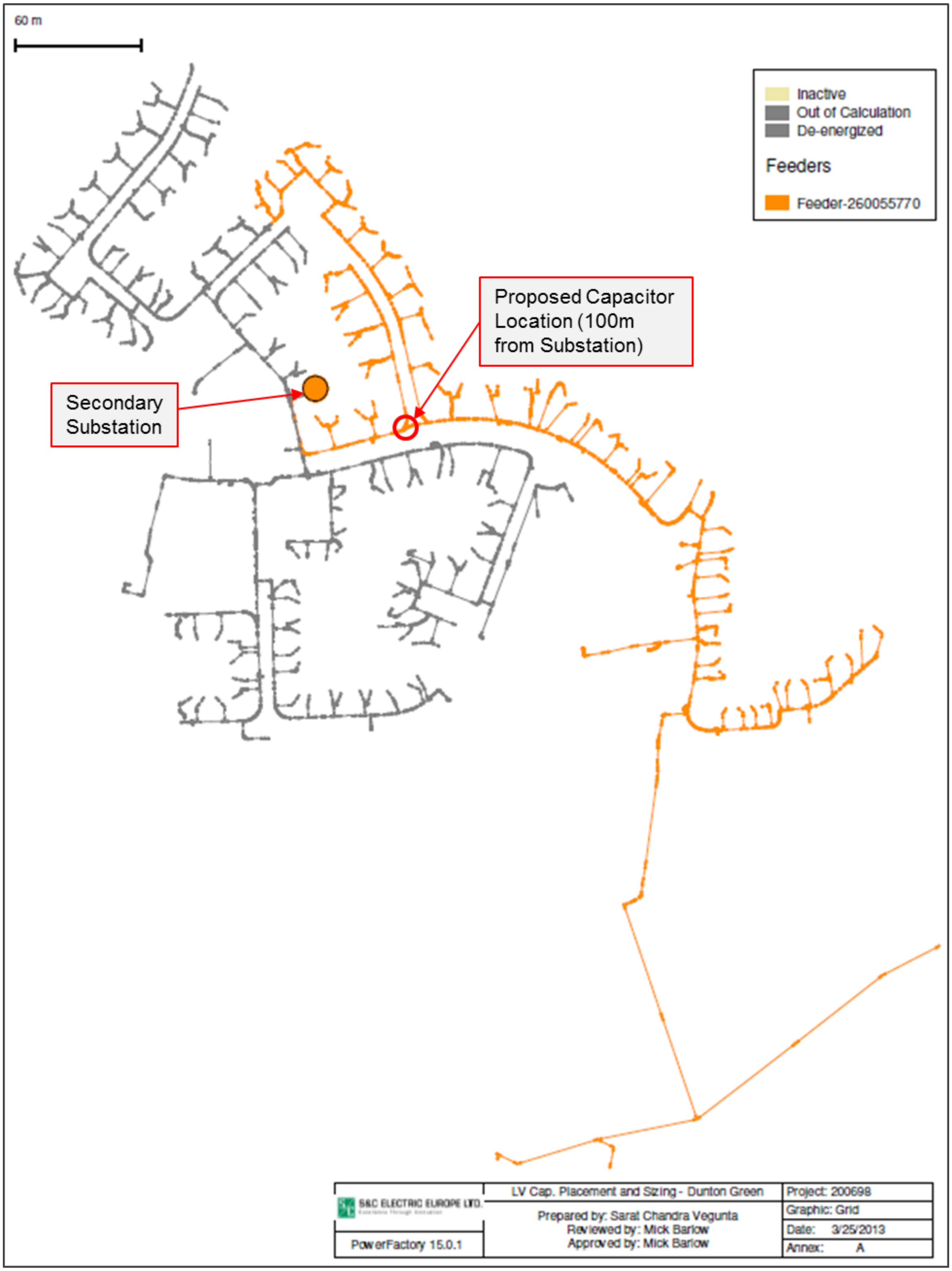

Figure B6 – Dunton Green LV Network

Appendix C. NETWORK DATA

Network Voltage Limits:

- LV statutory limits: 0.94p.u. to 1.10p.u of 230V nominal voltage
- HV voltage tolerances: 0.94p.u. to 1.06p.u of 11kV or 6.6kV nominal voltage

Secondary Transformer Data:

- DYn11, HV/0.433kV (250V L-N)
- Transformer HV nominal voltages at study substations were provided as following: 6.6kV - Greenside Lane Fiveways, 11kV - Edge Green Lane, 6.6kV - Howard Street, 11kV – Landgate, 11kV - Leicester Avenue, 11kV - Dunton Green
- Solid Ground LV Earth, 5 taps on HV side @ 2.5% per tap step, nominal tap position is 3
- Zero sequence impedances will be assumed as 85% of positive sequence
- Transformer impedances to be taken from ENW Feeder Calculation Spreadsheet provided for Mayorlowe Avenue from S&C's '300419-ENW-LV Network Voltage Studies' project

LV Network Circuit Type Data and Assumptions:

- The zero sequence impedances, R0' and X0', for three-core and four-core cables will be assumed as sum of normal phase impedance and three times the fault earth return impedance
- The neutral conductor impedances (Rn', Xn'), for two-core and four-core cable were assumed as equal to normal phase impedances, while for three-core cables, the neutral impedances will be considered as given
- The mutual impedances (Rpn', Xpn') for all LV cables were not considered, and therefore a value of zero for these impedances was applied in the PowerFactory models.
- Typical positive sequence capacitances (C') were assumed
- The zero sequence capacitances (C0') were assumed as equal to positive sequence capacitance values
- kVA rating and impedances to be taken from ENW Feeder Calculation Spreadsheet provided for Mayorlowe Avenue from S&C's '300419-ENW-LV Network Voltage Studies' project

Table C1 – LV Network Cable Type Data

Cable Name	Current	Phases	R'	X'	R0'	X0'	Rn'	Xn'	C'	C0'	Cn'
	A		Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	uF/km	uF/km	uF/km
2c 0.007 Service	-	1	3.970	0.099	0.215	0.074	3.970	0.099	0.270	0.861	0.270
2c 0.0145 Service	-	1	1.903	0.090	0.625	0.109	1.903	0.090	0.350	0.760	0.350
2c 0.0225 Service	-	1	1.257	0.085	0.805	0.092	1.257	0.085	0.380	0.604	0.380
2c 16 PSC Service	-	1	1.150	0.088	1.489	0.091	1.150	0.088	0.350	0.450	0.350
2c 25 PSC Service	-	1	0.727	0.092	0.690	0.078	0.727	0.092	0.380	0.350	0.380
2c 35 SAC XC Service	-	1	0.868	0.077	0.958	0.079	0.868	0.077	0.420	0.537	0.420
2c 35 SAC XSC Service	-	1	0.868	0.092	0.534	0.078	0.868	0.092	0.420	0.693	0.420
2c 4 XLPE Service	-	1	4.610	0.091	0.690	0.079	4.610	0.091	0.270	0.612	0.270
3c 185 Waveform	305	3	0.166	0.074	0.664	0.113	0.166	0.074	0.699	0.699	0.699
3c 240 Waveform	355	3	0.127	0.073	0.625	0.109	0.127	0.073	0.760	0.760	0.760
3c 25 SAC XC Service	100	3	1.200	0.077	5.100	0.116	1.200	0.077	0.370	0.370	0.370
3c 300 Consac	385	3	0.102	0.068	0.384	0.086	0.102	0.068	0.791	0.791	0.791
3c 300 Waveform	400	3	0.102	0.073	0.600	0.106	0.102	0.073	0.612	0.612	0.612
3c 95 Consac	195	3	0.322	0.069	1.201	0.096	0.322	0.069	0.699	0.699	0.699
4c 0.00225 Service	90	3	1.257	0.086	4.611	0.113	1.257	0.086	0.300	0.300	0.300
4c 0.0145 Service	55	3	1.903	0.089	5.251	0.149	1.903	0.089	0.230	0.230	0.230
4c 0.04 Cu PILC (Bond)	115	3	0.708	0.079	2.319	0.094	0.708	0.079	0.358	0.358	0.358
4c 0.06 Cu PILC (Bond)	150	3	0.469	0.075	1.582	0.090	0.469	0.075	0.399	0.399	0.399
4c 0.1 Cu PILC (Bond)	200	3	0.274	0.073	0.958	0.079	0.274	0.073	0.537	0.537	0.537
4c 0.1 Cu PILC (SNE)	200	3	0.274	0.073	1.945	0.082	0.274	0.073	0.537	0.537	0.537
4c 0.1 SAC (Bond)	155	3	0.451	0.073	1.489	0.091	0.451	0.073	0.450	0.450	0.450
4c 0.12 Cu PILC (Bond)	230	3	0.242	0.072	0.851	0.078	0.242	0.072	0.577	0.577	0.577
4c 0.15 Cu PILC (Bond)	260	3	0.195	0.070	0.690	0.079	0.195	0.070	0.612	0.612	0.612
4c 0.2 Cu PILC (Bond)	310	3	0.150	0.069	0.534	0.078	0.150	0.069	0.693	0.693	0.693
4c 0.2 Cu PILC (SNE)	310	3	0.150	0.069	1.188	0.081	0.150	0.069	0.693	0.693	0.693
4c 0.2 SAC (Bond)	240	3	0.230	0.069	0.782	0.084	0.230	0.069	0.601	0.601	0.601
4c 0.25 Cu PILC (Bond)	355	3	0.124	0.069	0.442	0.078	0.124	0.069	0.629	0.629	0.629

Cable Name	Current	Phases	R'	X'	R0'	X0'	Rn'	Xn'	C'	C0'	Cn'
	A		Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	uF/km	uF/km	uF/km
4c 0.3 Cu PILC (Bond)	400	3	0.106	0.068	0.379	0.077	0.106	0.068	0.699	0.699	0.699
4c 0.3 Cu PILC (SNE)	400	3	0.106	0.068	0.877	0.077	0.106	0.068	0.699	0.699	0.699
4c 0.3 SAC (Bond)	305	3	0.150	0.068	0.522	0.083	0.150	0.068	0.733	0.733	0.733
4c 0.35 Cu PILC (Bond)	150	3	0.089	0.068	0.319	0.076	0.089	0.068	0.750	0.750	0.750
4c 0.5 Cu PILC (Bond)	525	3	0.059	0.067	0.215	0.073	0.059	0.067	0.791	0.791	0.791
4c 0.6 Cu PILC (Bond)	677	3	0.050	0.162	0.198	0.072	0.050	0.162	0.837	0.837	0.837
4c 0.7 Cu PILC (Bond)	874	3	0.059	0.067	0.215	0.074	0.059	0.067	0.861	0.861	0.861
4c 120 SAC (Bond)	230	3	0.255	0.068	0.885	0.080	0.255	0.068	0.693	0.693	0.693
4c 16 Cu PILC Service	95	3	1.149	0.080	4.260	0.092	1.149	0.080	0.350	0.350	0.350
4c 185 SAC (Bond)	295	3	0.166	0.068	0.580	0.077	0.166	0.068	0.699	0.699	0.699
4c 185 Waveform (Bond)	305	3	0.166	0.073	0.412	0.094	0.166	0.073	0.699	0.699	0.699
4c 25 SAC	125	3	1.200	0.079	1.300	0.079	1.200	0.079	0.370	0.370	0.370
4c 300 Waveform (Bond)	400	3	0.102	0.072	0.291	0.087	0.102	0.072	0.791	0.791	0.791
4c 70 SAC (SNE)	165	3	0.446	0.071	2.540	0.092	0.446	0.071	0.537	0.537	0.537
4c 95 Waveform (Bond)	205	3	0.322	0.074	0.805	0.092	0.322	0.074	0.604	0.604	0.604
5c 0.01 Cu	25	3	0.274	0.073	0.959	0.079	0.274	0.073	0.320	0.320	0.320
5c 0.015 Cu	31	3	0.195	0.070	0.690	0.078	0.195	0.070	0.350	0.350	0.350
5c 0.04 Cu	56	3	0.708	0.079	2.320	0.093	0.708	0.079	0.270	0.270	0.270
5c 0.06 Cu	71	3	0.469	0.075	1.581	0.091	0.469	0.075	0.300	0.300	0.300

Appendix D. FEEDER VOLTAGE PROFILES - WITH NO CAPACITORS

Results below are for all study feeders and considered load scenarios (A1 to B3) summarised in Table 3.

Green Side Lane:

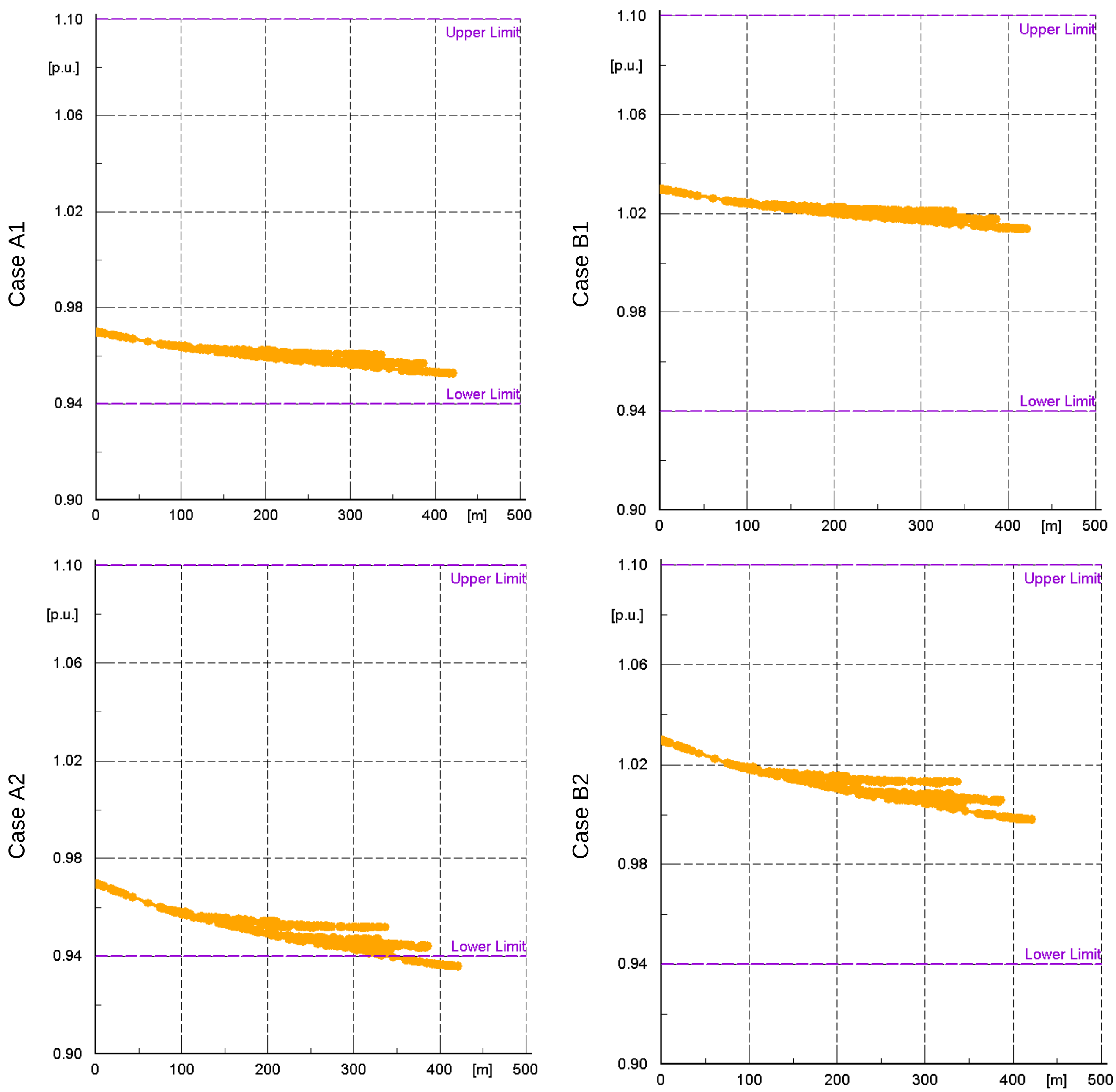

Figure D1 – Feeder#527400008 Voltage Profiles without Capacitors (Cases A1, A2, B1, and B2)

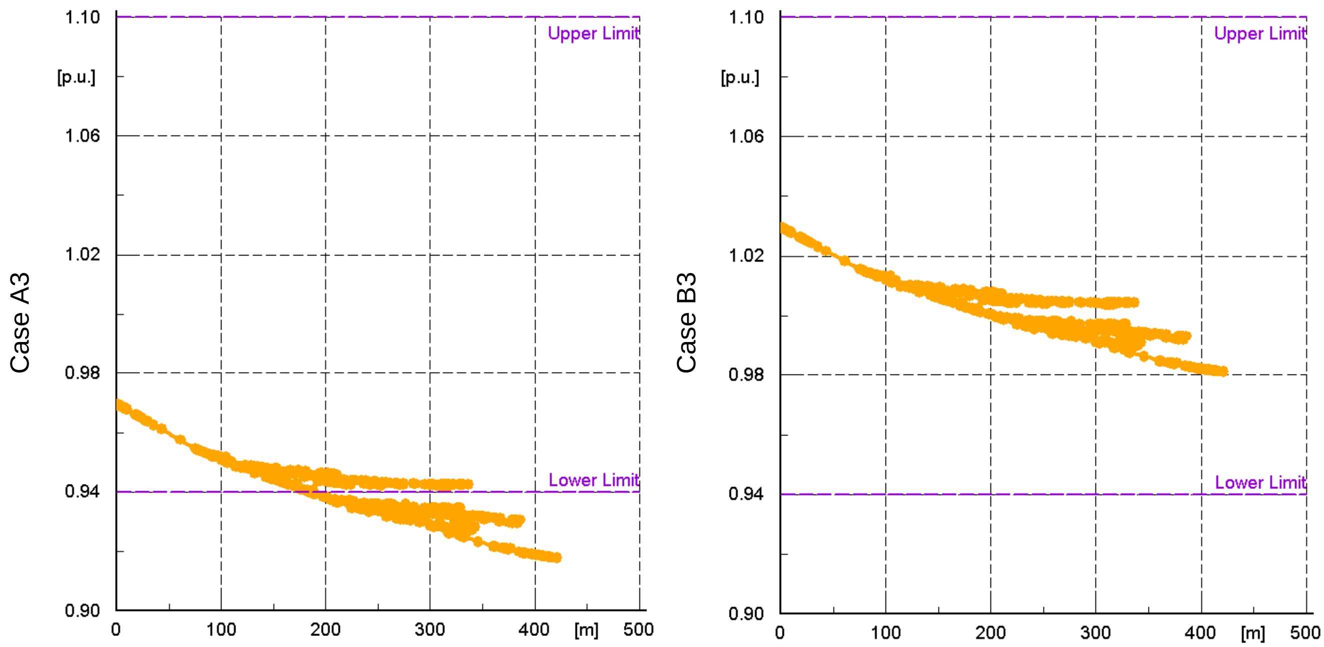

Figure D2 – Feeder#527400008 Voltage Profiles without Capacitors (Cases A3 and B3)

<u>Edge Green Lane</u>:

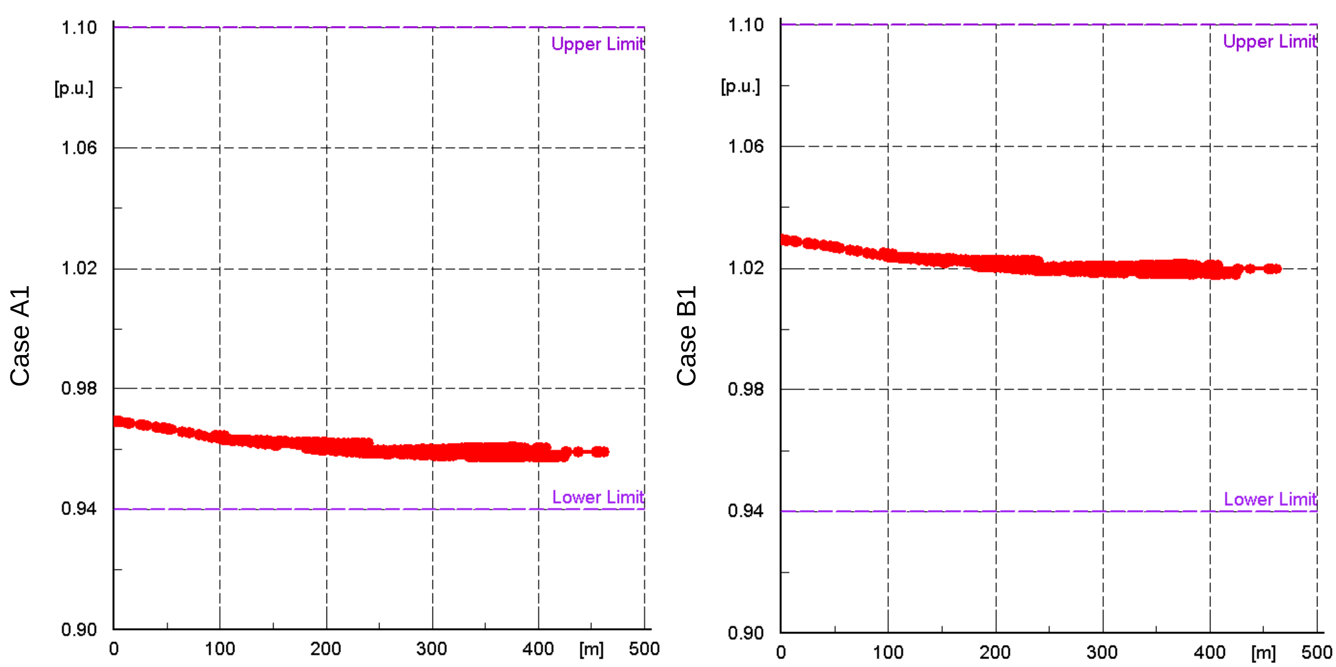

Figure D3 – Feeder#66074753 Feeder Voltage Profiles without Capacitors (Cases A1 and B1)

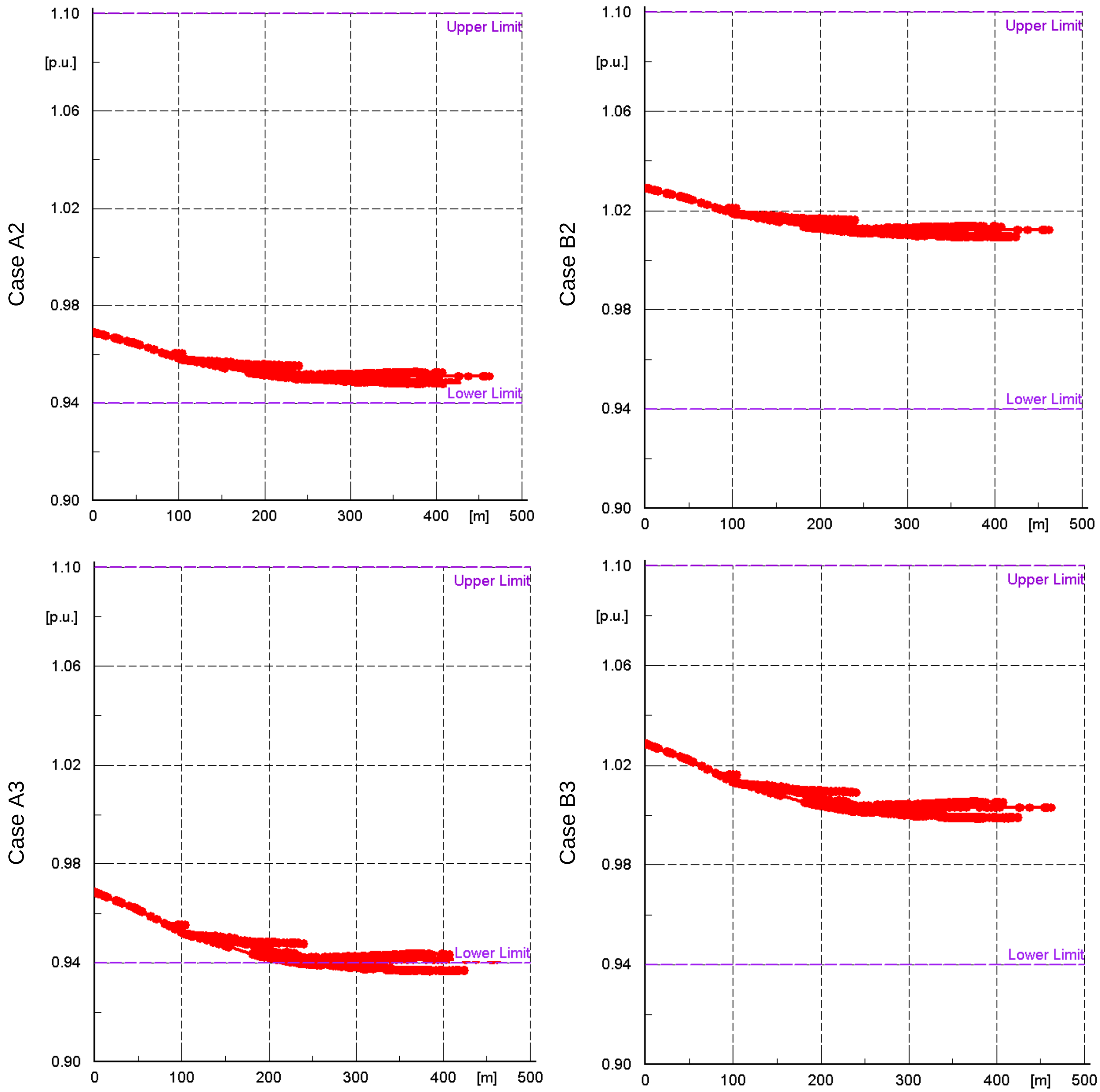

Figure D4 – Feeder#66074753 Voltage Profiles without Capacitors (Cases A2, A3, B2, and B3)

<u>Howard Street</u>:

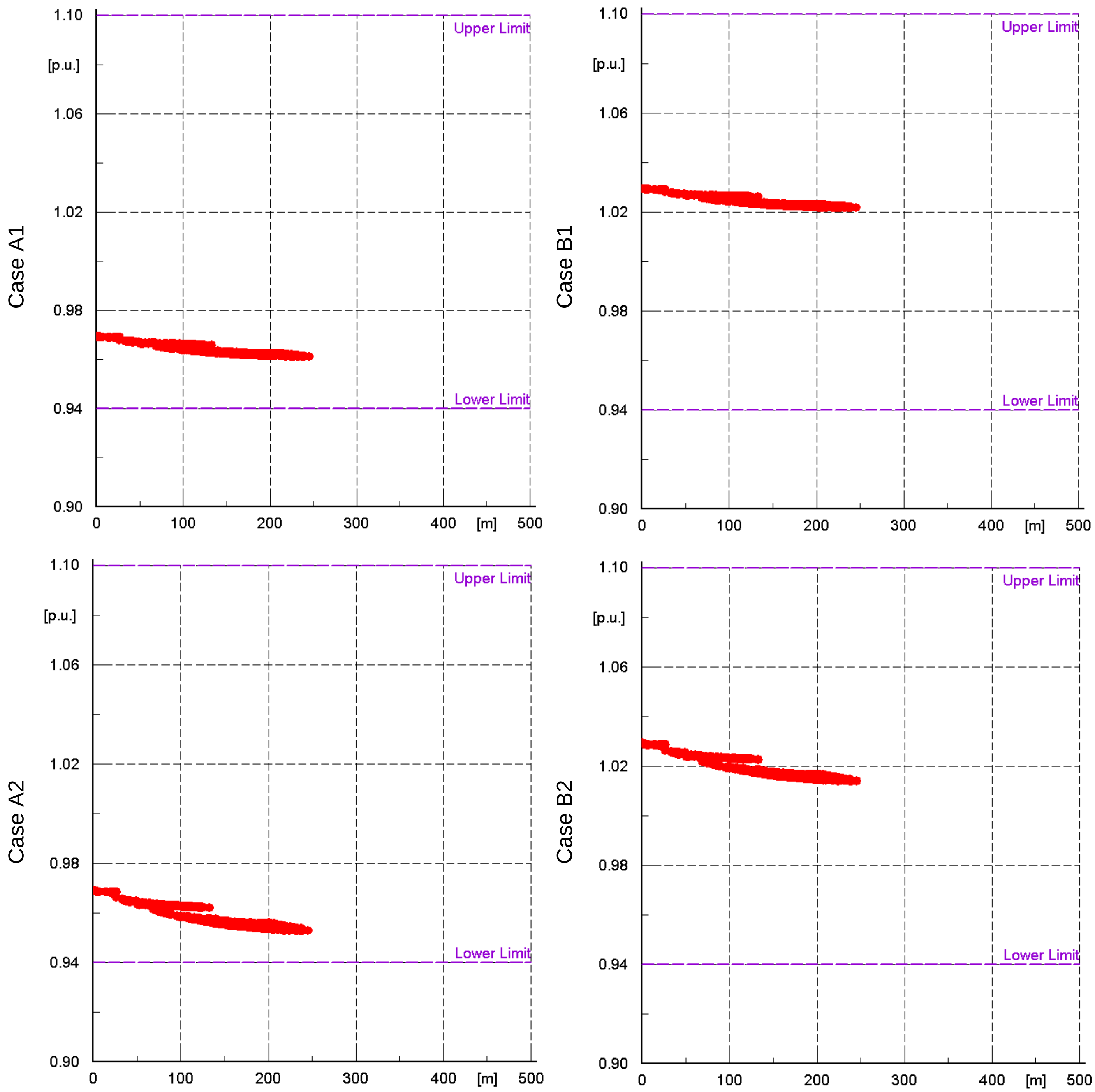

Figure D5 – Feeder#216044696 Voltage Profiles without Capacitors (Cases A1, A2, B1, and B2)

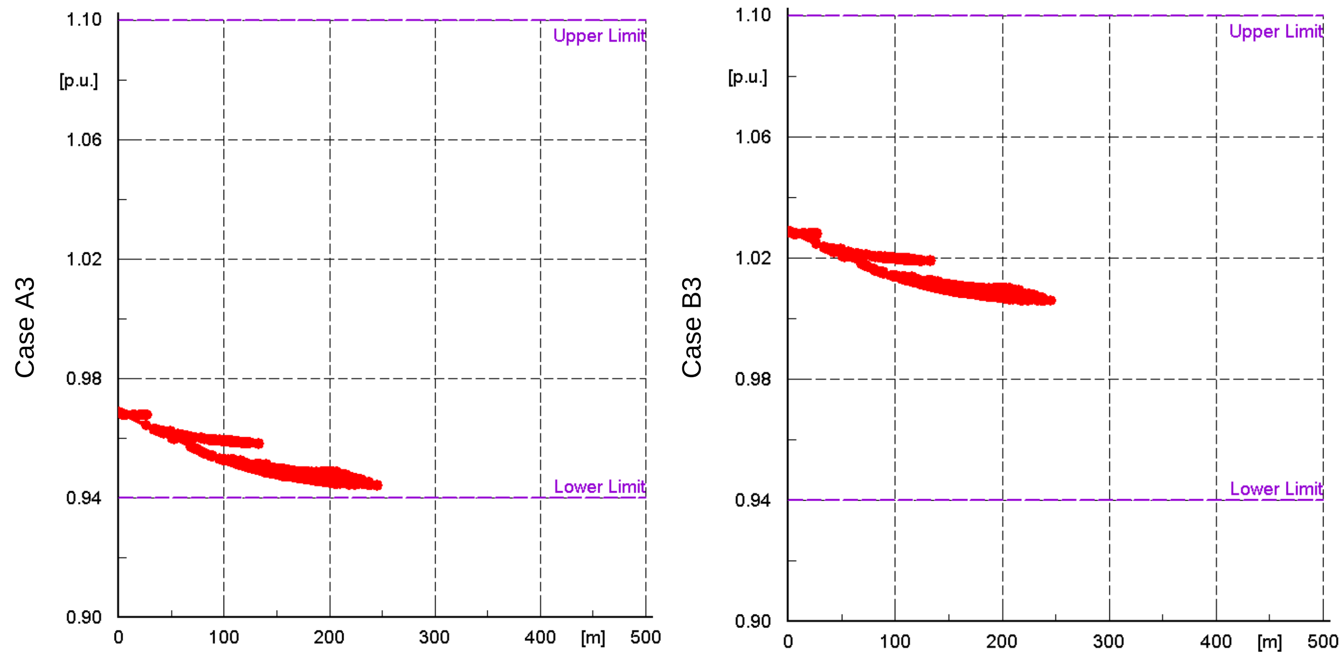

Figure D6 – Feeder#216044696 Voltage Profiles without Capacitors (Cases A3 and B3)

Landgate:

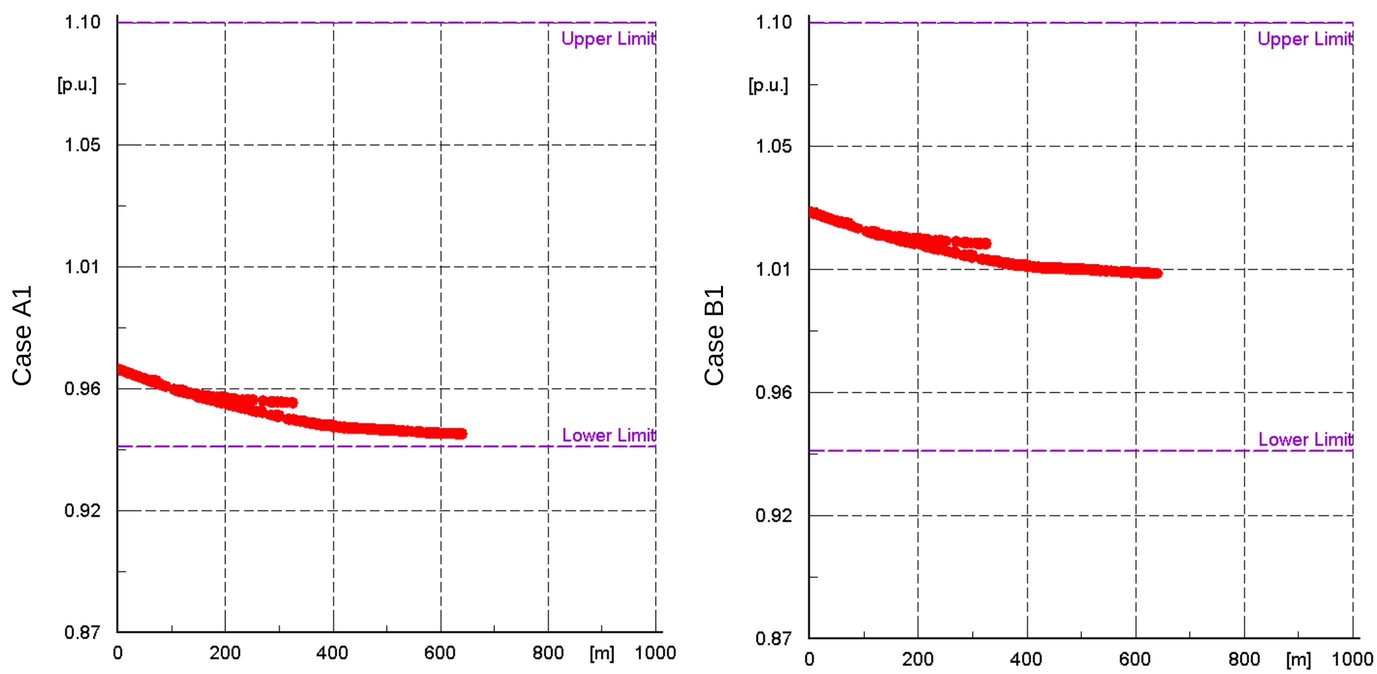

Figure D7 – Feeder#63057172 Voltage Profiles without Capacitors (Cases A1 and B1)

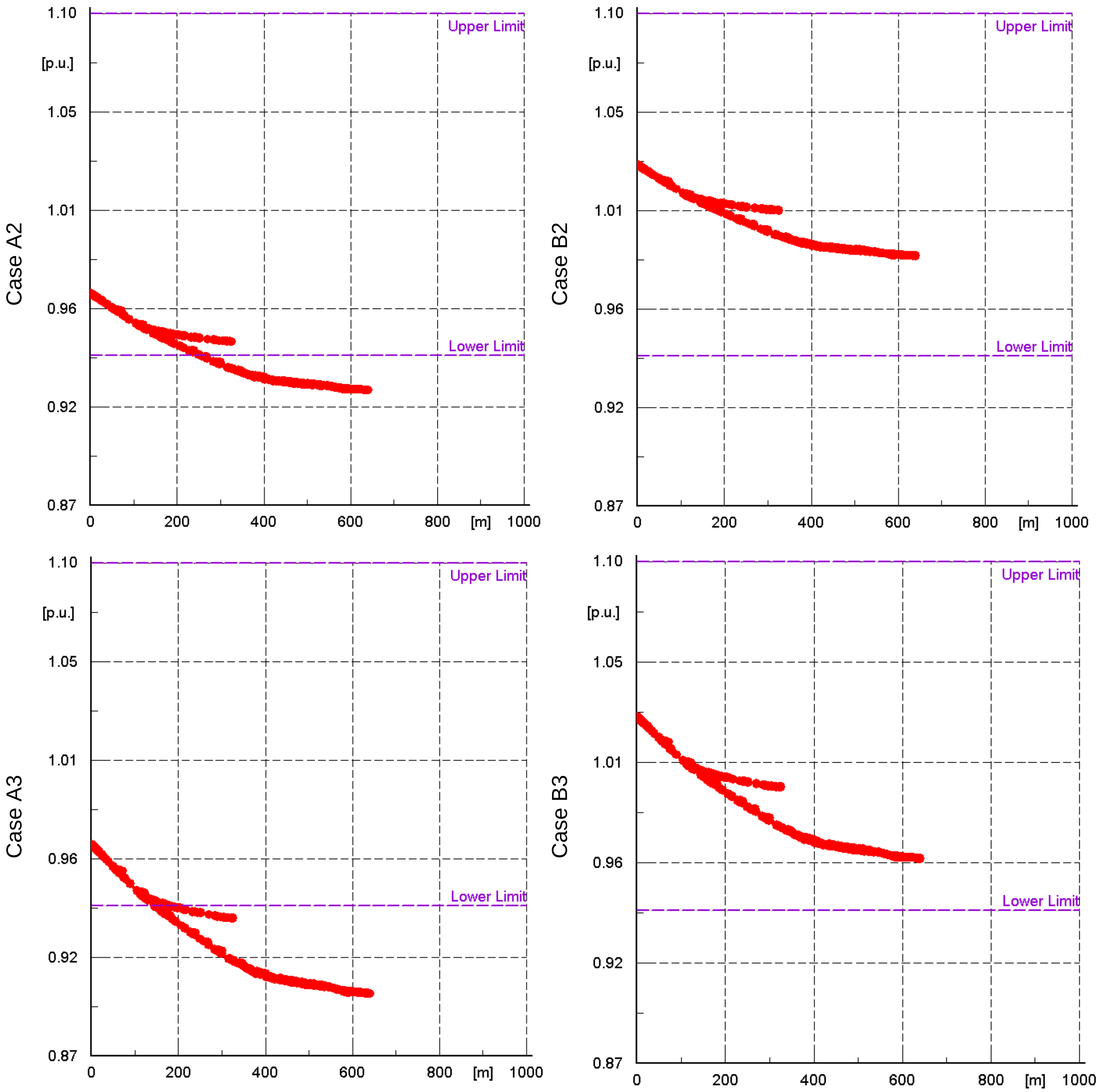

Figure D8 – Feeder#63057172 Voltage Profiles without Capacitors (Cases A2, A3, B2, and B3)

Leicester Avenue:

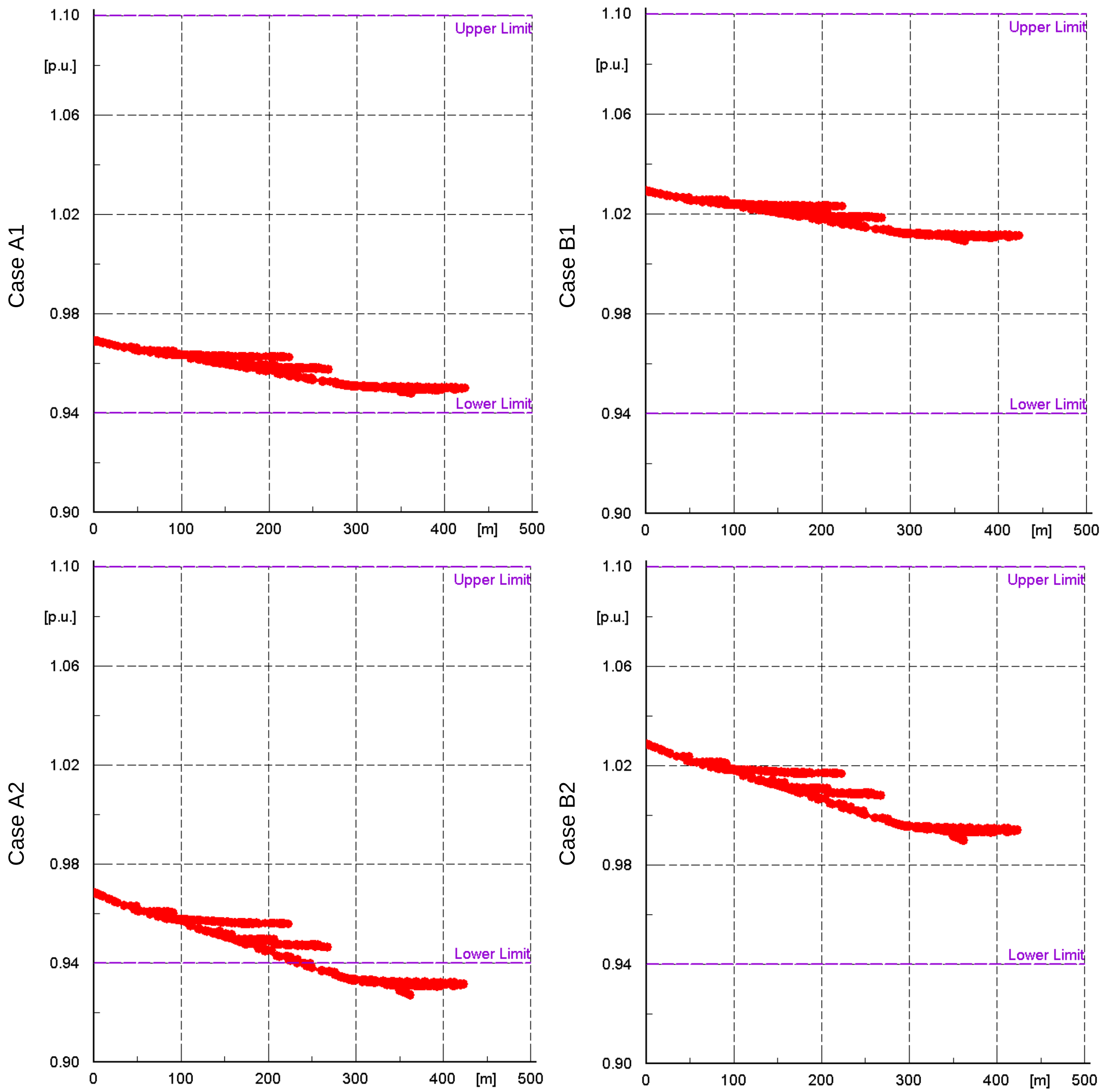

Figure D9 – Feeder# 69051565 Voltage Profiles without Capacitors (Cases A1, A2, B1, and B2)

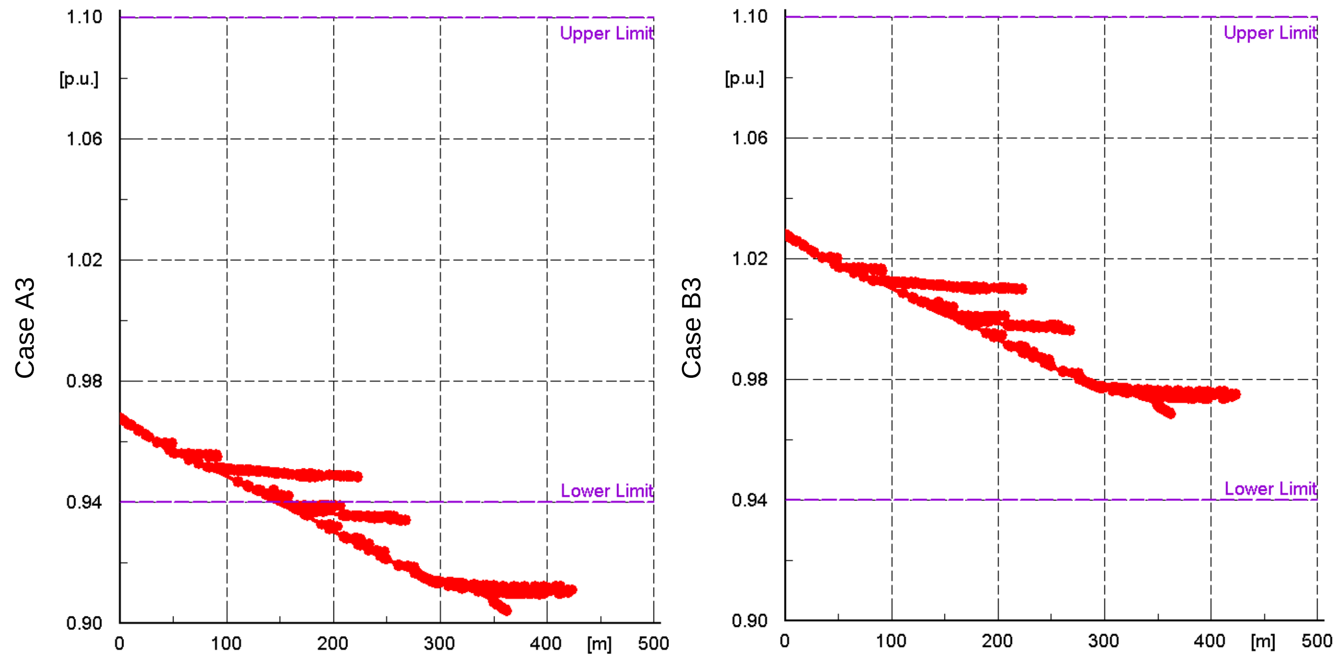

Figure D10 – Feeder# 69051565 Voltage Profiles without Capacitors (Cases A3 and B3)

<u>Dunton Green</u>:

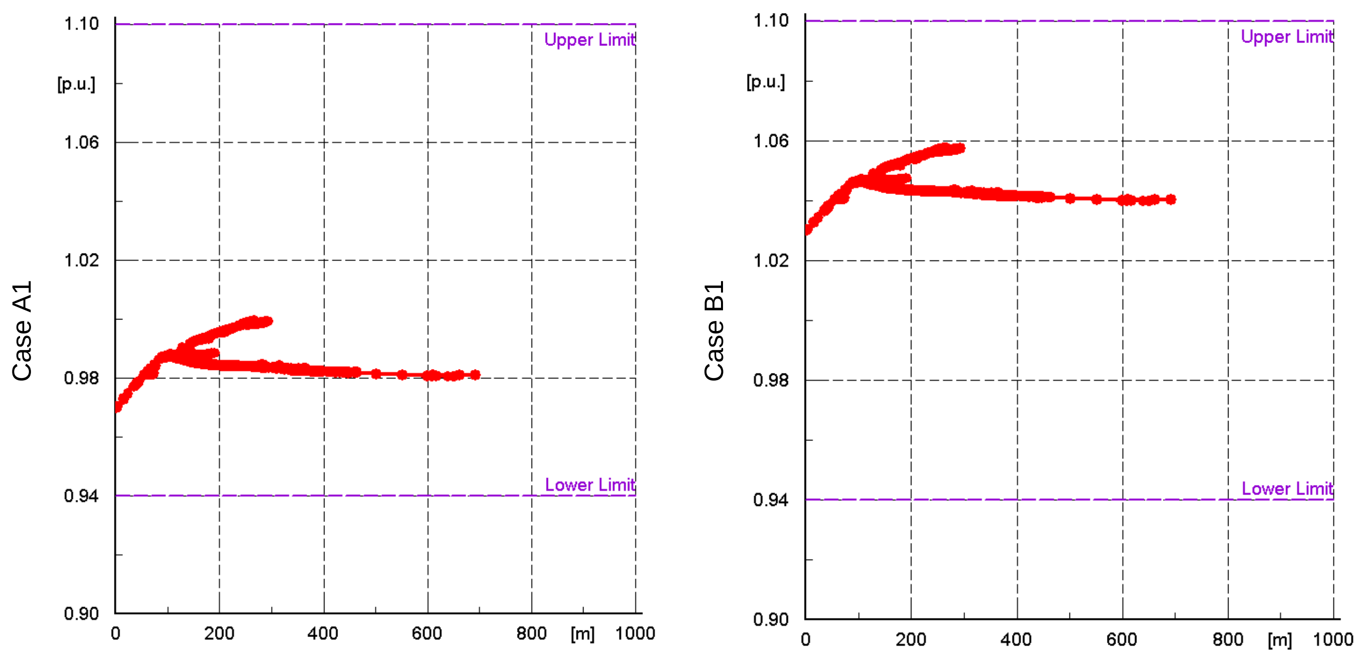

Figure D11 – Feeder# 260055770 Voltage Profiles without Capacitors (Cases A1 and B1)

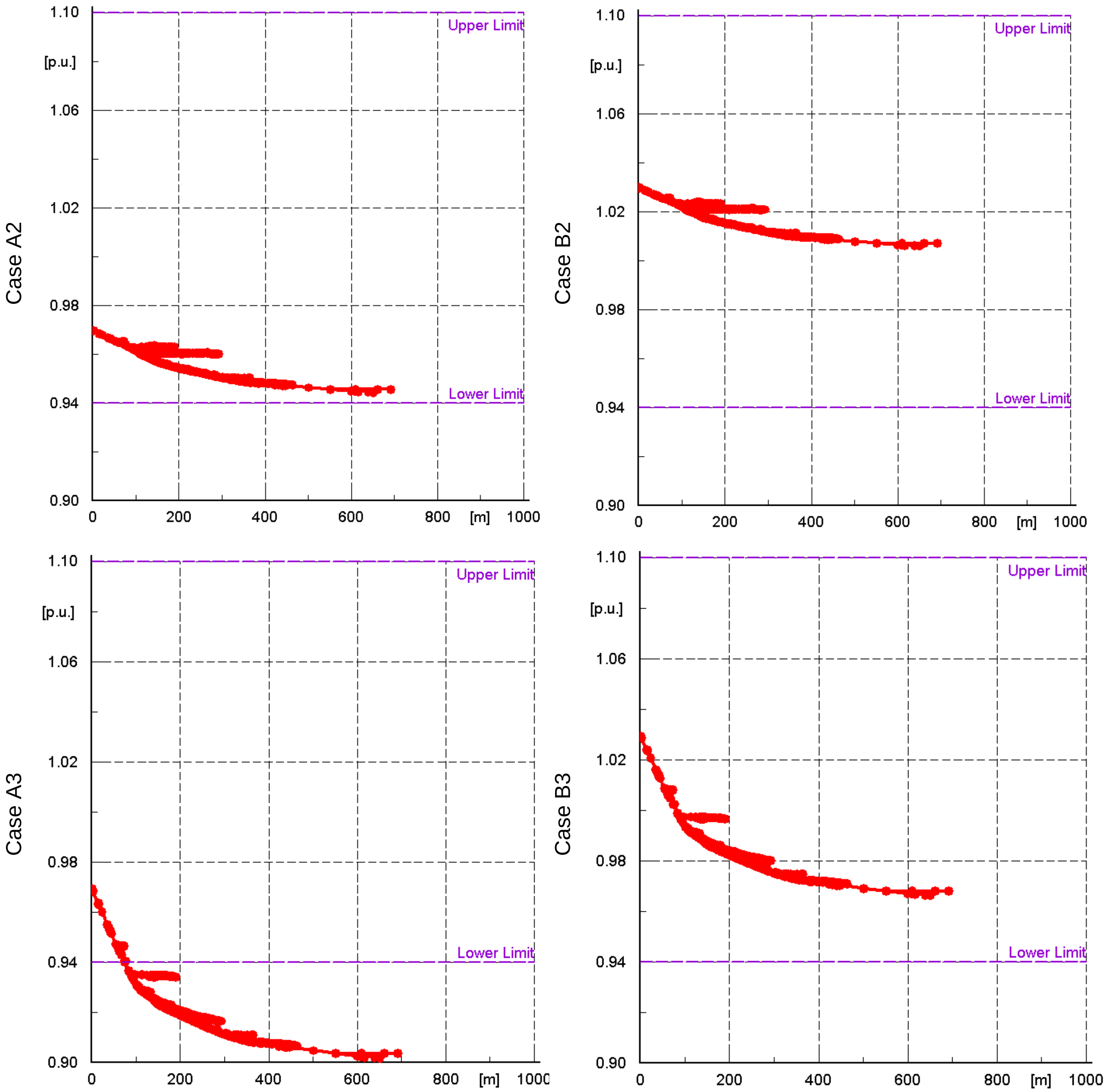

Figure D12 – Feeder# 260055770 Voltage Profiles without Capacitors (Cases A2, A3, B2, and B3)