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LEONARDS HILL WIND FARM

SYSTEM STUDIES
VOLTAGE, REACTIVE, FEEDER LOADING, FAULT LEVELS
(Revised)

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LEONARDS HILL WIND FARM
SYSTEM STUDIES
VOLTAGE, REACTIVE, FEEDER LOADING AND FAULT LEVELS

EXECUTIVE SUMMARY

The interaction of the proposed Leonards Hill wind farm with the Powercor distribution network has been investigated. The investigation was carried out to determine the operational measures necessary to ensure the wind farm would operate within the requirements of the Victorian Electricity Distribution Code. The studies indicated that the wind farm could operate within the requirements for customer voltage and line loading.

CONCLUSIONS

1 The wind farm should be operated at a power factor of 0.90 absorbing to ensure the voltage changes for variations in generation level would not cause disturbance to customers.

2 With the wind farm operating at a power factor of 0.90 absorbing, the variation in voltage for generation changing from zero to 4MW in normal operation would be up to about 1.7%.

3 The change in voltage for a trip of the full 4MW of wind farm generation would be up to 1.8%. A trip of both turbines at full generation would be a rare event.

4 The change in voltage for a typical change in generation of about 25% would be up to about 0.3%.

5 These changes in voltage should not disturb customer supply.

6 The loading of the feeder due to wind farm operation would be well within the feeder rating.

7 The infeed of fault current from the wind farm would cause a small increase in the three phase and single phase to ground fault currents.

LEONARDS HILL WIND FARM
SYSTEM STUDIES
VOLTAGE, REACTIVE, FEEDER LOADING AND FAULT LEVELS

1.0 SYSTEM CONNECTION

The connection of the proposed Leonards Hill wind farm to the BAN_11 22kV feeder on the Powercor network is indicated by Figure 1. This diagram includes the points on the feeder for which the Powercor data indicated a load supplied directly from the feeder or from a T connected to the feeder.

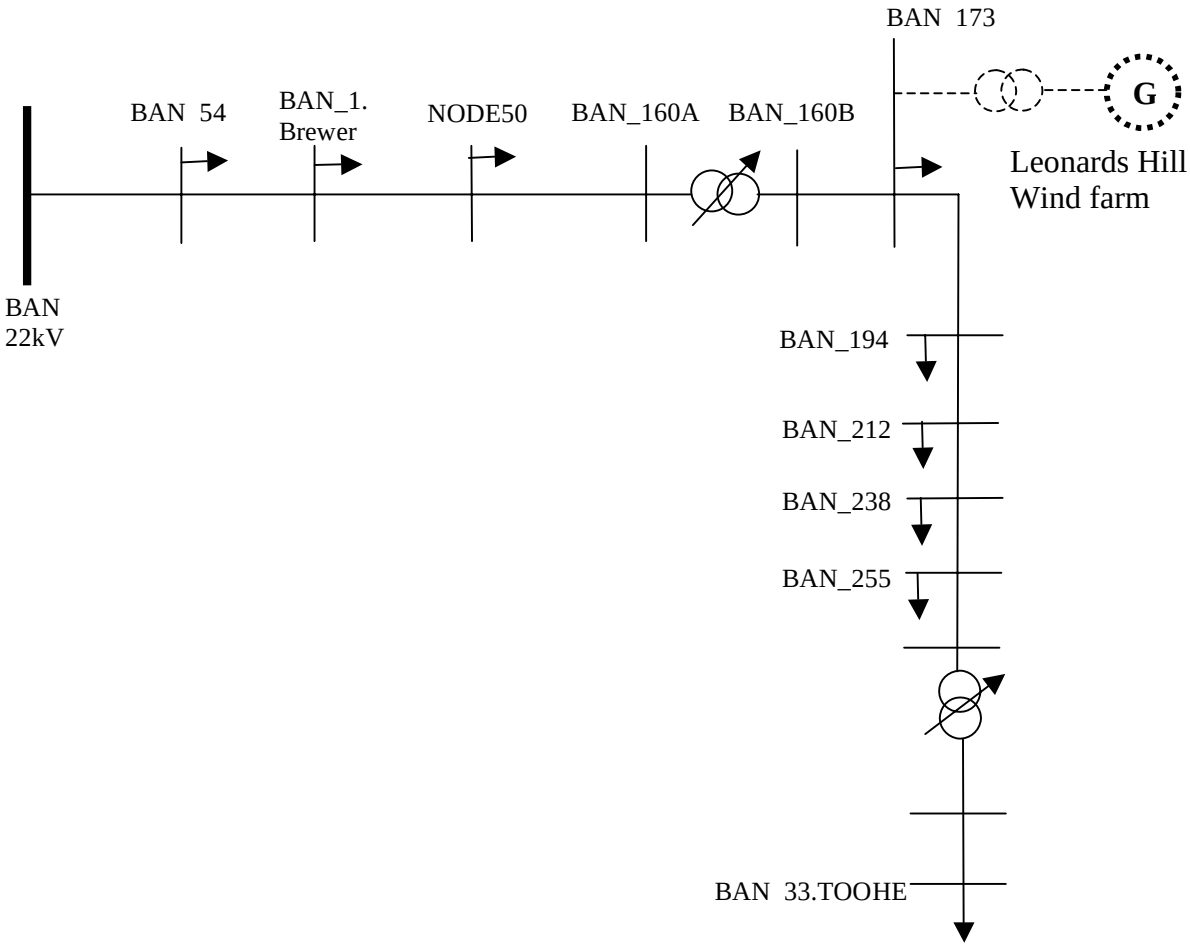

Figure 1 Connection of Leonards Hill Wind Farm to Powercor Feeder BAN_11

2.0 BASIS OF STUDIES

2.1 Feeder Model

The feeder was modeled using data supplied by Powercor. This data comprised:-

- impedances of feeder sections
- feeder current ratings

2.2 External System Model

The external system was modeled using the Thevenin impedance obtained from the fault current data supplied by Powercor. This impedance enabled the voltage change for sudden generation changes (eg generation trip) to be determined.

2.3 System Loads

The loads were modeled using data supplied by Powercor for maximum demand. This data included load currents and power factors. The loads for minimum demand were obtained for 30% of the maximum demand. The loads were modeled with some voltage sensitivity to enable determination of the effect of sudden changes in generation. The model used was 60% constant load and 40% constant impedance. This model is commonly used by Powercor Networks. The constant impedance component of the load was adjusted according to the bus voltages to ensure the total load current corresponded to the value provided by Powercor. An investigation of various load models indicated that the voltage profile was basically independent of the load model. The model used facilitates solution with PSSE. The loads are shown in Table 1.

Load Point	**Amps**	**Pf**	**tan phi**	**V**	**MVA**	**MW**	**MVAr**
				pu			
Node54	8.8	0.88	0.539743	1.00	0.34	0.30	0.16
BAN_1.Brewer	9.5	0.9	0.484322	0.96	0.35	0.31	0.15
Node50	16	0.9	0.484322	0.93	0.57	0.51	0.25
BAN_173	51.6	0.9	0.484322	1.02	2.01	1.81	0.87
BAN_194	2.8	0.9	0.484322	50.00	5.33	4.80	2.33
BAN_212	22.4	0.9	0.484322	1.01	0.86	0.78	0.38
BAN_238	3.5	0.9	0.484322	1.00	0.13	0.12	0.06
BAN_255	101.4	0.9	0.484322	0.99	3.83	3.44	1.67
BAN_33	17.9	0.9	0.484322	0.99	0.68	0.61	0.29
Total MW/MVAr						12.67	6.15
Regulator change in current	22.1						
Total amps	256						

Table 1 BAN_11 Feeder Loads

The substation demand corresponding to high loading of BAN_11 was obtained from substation load characteristic data supplied by Powercor. This substation demand was used to determine the substation transformer tap.

2.4 Wind Farm Generation

The wind farm generation was modeled as two 2MW wind turbines. The generators were connected to the system by separate 22kV/690Volt transformers.

2.6 Transformer and regulators

The zone substation transformer was represented by the voltage/load regulation characteristic. The regulators were represented by their reactance, tapping range and voltage/load regulation characteristic.

2.7 Regulatory Requirements

The wind farm performance was examined for satisfaction of the requirements of the Victorian Electricity Distribution Code (VEDC.)

3.0 WIND FARM ELECTRICAL ARRANGEMENT

The electrical arrangement proposed for the wind farm is indicated in Figure 2.

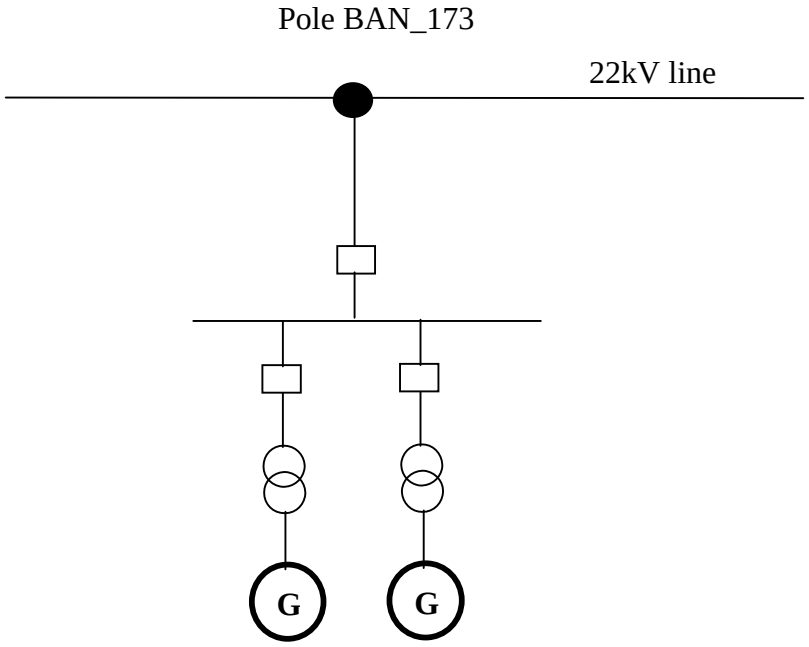

Figure 2 Wind Farm Electrical Arrangement

4.0 VOLTAGE AND REACTIVE CONTROL

4.1 Basis of Voltage Control Design

The voltage conditions and reactive control were investigated on the basis that the wind farm should only cause a minor change in the customer supply voltages to avoid disturbance to customer supply. The power output of the wind farm causes a voltage rise at the wind farm. This can be compensated by causing the wind farm to import reactive power.

On this basis, the feeder voltage profiles were determined for a range of generator operating power factors.

4.0 VOLTAGE AND REACTIVE CONTROL

4.2 Steady State Conditions - High Load

The results of studies for high load conditions are shown in Tables A1, A2, A3 in Appendix A. The results are shown graphically in Figures A1, A2, A3 in Appendix A.

a) Wind farm operating at 1.00 power factor at the 22kV connection point (Figure A1)

- With zero generation the feeder voltage falls from about 1.03 pu at the zone substation to about 0.93 pu at NODE50 and to about 0.925 pu at the Bungaree regulator at BAN_160A.
- With 4MW generation operating at unity power factor, the feeder voltage at BAN_160A would increase from 0.925 with no generation to about 0.97 ie an increase of about 4.5%.
- With zero generation, the Bungaree regulator would restore the voltage at BAN_160 to about 1.035 pu,
- As the generation increases, the Bungaree regulator would detect a reduction in the flow through the regulator and would therefore reduce the target voltage for the regulator tap changer.
- The voltage at points supplied from the regulator would be affected by the voltage at BAN_160A and the regulator tap boost,
- This would result in the voltage at BAN160B being reduced to about 1.015 pu ie a reduction of 2%. Similar reductions in voltage would occur for the voltages at points supplied from the feeder after the regulator.
- The network supplied from the Muskvale regulator was modeled as a single load at BAN_33 as indicated in the Powercor data. The flow through the regulator would be unaffected by the generation. The voltage at points supplied from the Muskvale regulator would be affected by the voltage determined by the Bungaree regulator. The voltage at BAN_33 would change from about 0.995 with zero generation to about 0.98 with 4MW of generation, a change of about 2%.

b) Wind farm operating at 0.90 and 0.95 power factor at the 22kV connection point

(Figures A2, A3)

The voltage change of 4% for loads supplied from NODE50 with operation at a power factor of 1.00 could cause an excessive disturbance to customer supply. The operation of the wind farm was therefore examined for operation at power factors of 0.95 and 0.90 at the 22kV connection point.

4.3 Steady State Conditions - Low Load

The results of studies for high load conditions are shown in Tables B1, B2, B3 in Appendix B. The results are shown graphically in Figures B1, B2, and B3 in Appendix B.

The results of studies at light load indicate that the variation in voltage is less than for high load. Operation with power factors from 0.90 to 1.00 with full 4MW generation would cause a variation in the voltage at BAN_160A ranging from 3% to 0.9%. This is consistent with the case from high load for operation of the wind farm with a power factor of 0.90 at the 22kV connection point.

4.0 VOLTAGE AND REACTIVE CONTROL

4.4 Steady State Conditions - Effect on Feeder Voltage of Varying Generator Power Factor (Generator absorbing reactive)

The effect of causing the wind farm to absorb reactive on the voltage at the critical location ie BAN160A is shown in Figures 3 and 4. These figures indicate that the most severe case is high load. For high load, the voltage change from zero to 4MW of generation could be reduced from 4.5% for a power factor of 1.00 to about 2.7% for a power factor of 0.95 absorbing and 1.7% for a power factor of 0.90% absorbing.

The wind turbine generation would typically vary between zero to full generation over a reasonably prolonged period eg an hour and customers would not see this change in a short time. Operation at 0.90 power factor absorbing is preferable to reduce the voltage change from 4.5% to 1.7%. More commonly, the generation could change by about 25% or 0.5MW over a matter of minutes. With operation with a power factor of 0.90 absorbing, this would produce a change in voltage of about 0.4% which would not normally cause any disturbance to customer perceptions of supply quality.

Operation at a power factor of 0.90 at the connection point is within the inherent capability of commercial wind turbines and is proposed as a requirement for the wind turbines.

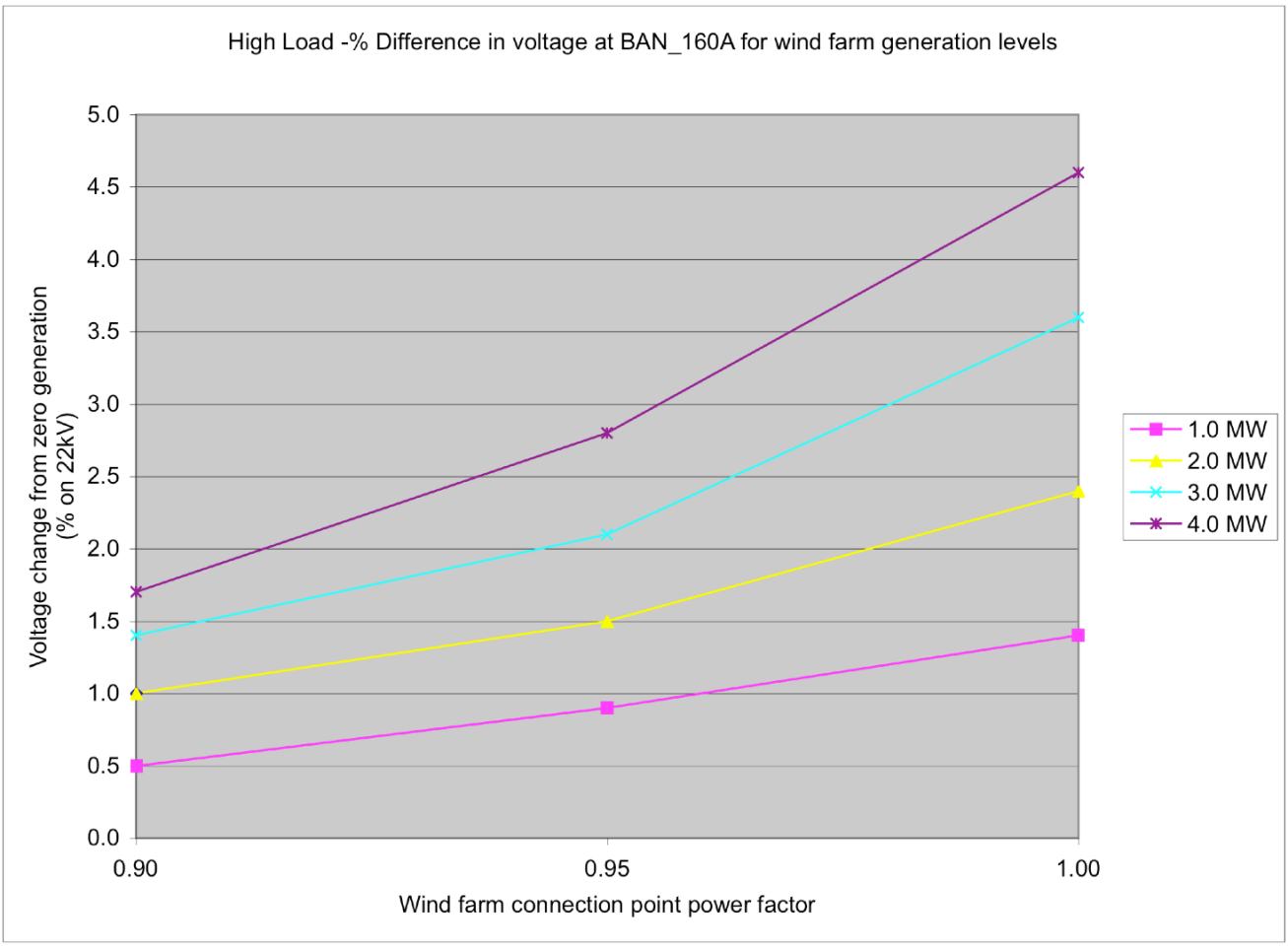

Figure 3

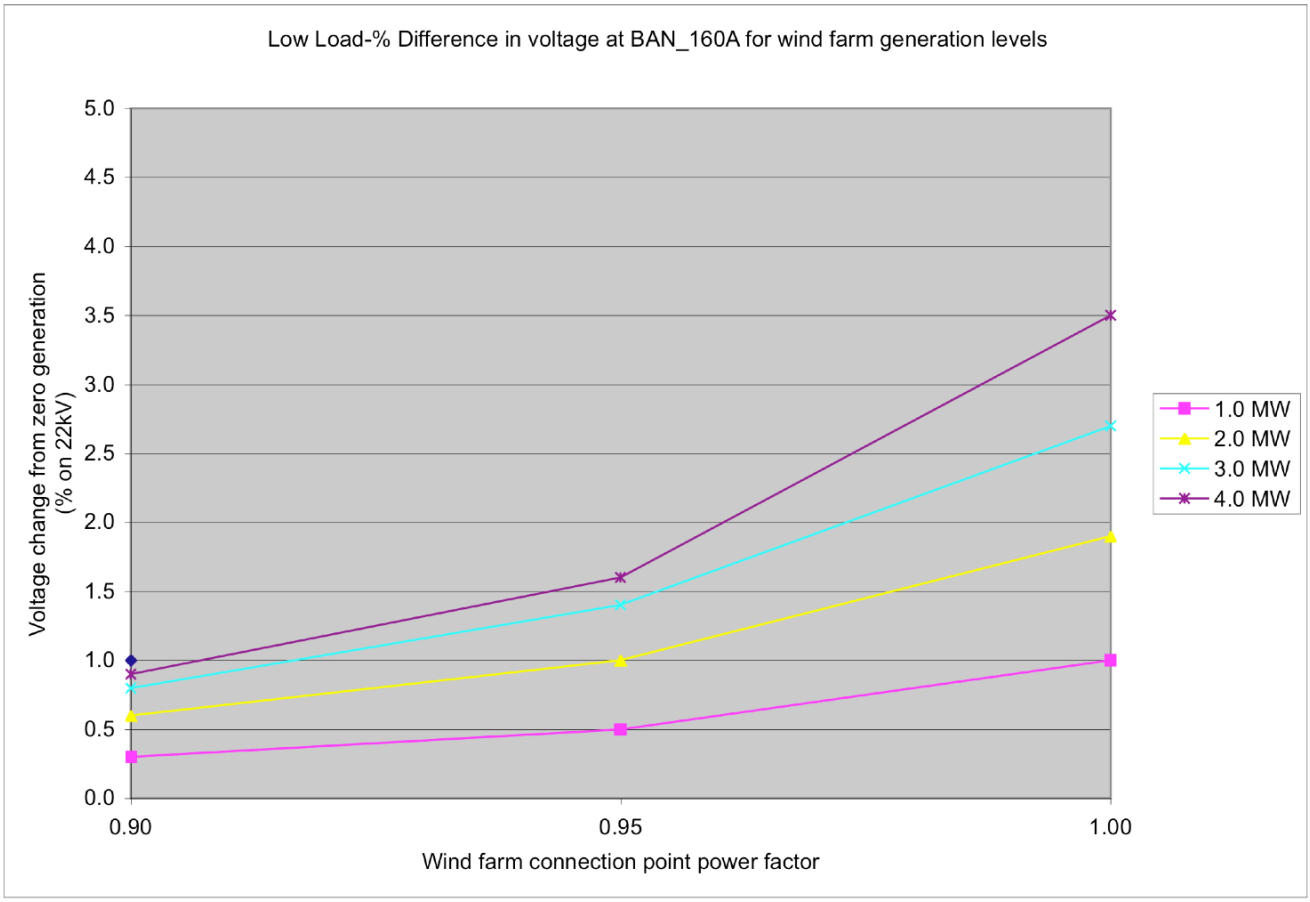

Figure 4

4.5 Effect of Generation Loss

The effects on feeder voltages of tripping the fully loaded generation at a power factor of 0.90 is shown on Table 2.

Load Level	**Change in Voltage for Wind Farm trip (% 22kV)**			
	Zone Sub	**BAN_160A**	**BAN_255**	**BAN_33**
Trip one wind turbine				
High Load	-0.1	-0.7	-0.9	0.8
Low Load	+0.2	-0.8	-0.6	-0.6
Trip 2 wind turbines				
High Load	-0.2	-1.3	-1.8	-1.7
Low Load	+0.2	-0.8	-1.1	-1.1

Note -ve voltage reduction, +ve voltage increase

Table 2

In general, tripping of either or both turbines at full power output would only occur for a fault in the turbine or turbine transformer. This operation would therefore be expected to be a rare event. The voltage change for tripping of the wind farm under typical generation levels would be about 40% of the values in Table 2 ie less than 1%.

5 LINE LOADING

The loading of feeder would be maximum for full 4MW generation and minimum load. The load sections affected are those from the connection point to the zone substation. The most critical section is from the connection point at BAN_173 to the regulator at BAN_160B. The loading on this section for the critical low load and high generation condition would be about 95 amps. This is well within the summer rating of 127 amps.

The loading on other feeder sections between BAN160A and the zone substation would be less critical because the current would be less and in most sections of the feeder, the conductor rating is higher.

There should therefore be no need for generation curtailment under high ambient temperature conditions.

6 FAULT LEVELS

The impact of the wind farm on fault levels at points along feeder BAN_11 are shown in Table 3. The wind farm was connected to the feeder by a 22kV/690V transformer connected DY ie the zero sequence network was open circuit.

Location	Three Phase (amps)		Single Phase to Ground (amps)	
	No Wind Farm	With Wind Farm	No Wind Farm	With Wind Farm
BAN_Zone Sub	10042	10472	11644	12022
BAN_54	4003	4447	2613	2728
BAN_1.Brewer	2437	2905	1423	1513
NODE_50	1887	2371	1088	1176
BAN_160	1791	2277	1037	1125
BAN_173	1640	2130	956	1045
BAN_194	1499	1905	869	943
BAN_212	1396	1741	798	861
BAN_238	1264	1542	711	761
BAN_255	1182	1423	658	701
BAN_33.TOOHE	1049	1235	574	608
BAN_143	710	794	373	389
BAN_183	661	733	345	359

Table 3

Note Wind Farm with 4MW at Leonards Hill

APPENDICES

Appendix A High Load
Appendix B Low Load

Appendix A High Load

Table A1 1.00 power factor
Table A2 0.95 power factor
Table A3 0.90 power factor

Figure A1 1.00 power factor
Figure A2 0.95 power factor
Figure A3 0.90 power factor

BAN 11 22kV Feeder - High Demand - 1.0pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.0	61.2	27.5	1.032	0.995	0.958	0.930	0.923	1.037	1.026	1.019	1.011	1.003	0.997	0.995	0.890	0.970
Sys-normal	0.5	0.0	60.6	27.4	1.033	0.998	0.963	0.936	0.930	1.033	1.022	1.015	1.007	0.999	0.993	0.992	0.900	0.970
Sys-normal	1.0	0.0	60.1	27.2	1.034	1.000	0.967	0.942	0.937	1.028	1.019	1.011	1.003	0.995	0.989	0.988	0.910	0.970
Sys-normal	1.5	0.0	59.6	27.3	1.035	1.003	0.972	0.948	0.941	1.027	1.018	1.010	1.002	0.994	0.989	0.987	0.917	0.970
Sys-normal	2.0	0.0	59.0	27.2	1.035	1.005	0.975	0.953	0.947	1.024	1.016	1.008	1.000	0.992	0.987	0.985	0.925	0.965
Sys-normal	2.5	0.0	58.5	27.2	1.036	1.008	0.979	0.958	0.953	1.023	1.015	1.007	0.999	0.991	0.985	0.984	0.932	0.970
Sys-normal	3.0	0.0	57.9	27.1	1.037	1.010	0.983	0.963	0.959	1.020	1.012	1.005	0.997	0.989	0.983	0.982	0.940	0.965
Sys-normal	3.5	0.0	57.4	27	1.038	1.012	0.987	0.968	0.964	1.017	1.010	1.003	0.995	0.987	0.981	0.979	0.948	0.965
Sys-normal	4.0	0.0	56.9	27	1.038	1.014	0.990	0.973	0.969	1.015	1.009	1.001	0.993	0.985	0.979	0.978	0.955	0.965

Table A1 High Feeder Demand, Generation Power Factor 1.00

BAN 11 22kV Feeder - Low Demand - 0.95pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.00	17.9	7.9	1.012	1.002	0.992	0.984	0.982	1.013	1.009	1.007	1.005	1.002	1.001	1.000	0.970	0.990
Sys-normal	0.5	-0.16	17.4	8.1	1.012	1.003	0.994	0.987	0.985	1.007	1.004	1.002	1.000	0.997	0.996	0.995	0.978	0.990
Sys-normal	1.0	-0.33	16.9	8.2	1.012	1.004	0.995	0.989	0.987	1.005	1.003	1.001	0.998	0.996	0.994	0.994	0.982	0.990
Sys-normal	1.5	-0.50	16.4	8.4	1.012	1.004	0.996	0.991	0.990	1.002	1.000	0.997	0.995	0.993	0.991	0.990	0.988	0.990
Sys-normal	2.0	-0.67	15.9	8.6	1.012	1.005	0.998	0.993	0.992	1.002	1.000	0.998	0.996	0.993	0.992	0.991	0.990	0.990
Sys-normal	2.5	-0.80	15.4	8.7	1.012	1.006	0.999	0.995	0.995	0.995	0.993	0.991	0.989	0.986	0.985	0.984	1.000	0.990
Sys-normal	3.0	-1.00	14.9	8.9	1.012	1.006	1.000	0.997	0.996	0.996	0.995	0.993	0.991	0.988	0.987	0.986	1.000	0.990
Sys-normal	3.5	-1.16	14.4	9.1	1.012	1.007	1.001	0.998	0.998	0.998	0.998	0.996	0.993	0.991	0.989	0.989	1.000	0.990
Sys-normal	4.0	-1.30	13.9	9.2	1.012	1.007	1.002	1.000	1.001	1.000	1.000	0.998	0.996	0.994	0.992	0.991	1.000	0.990

Table A2 High Feeder Demand, Generation Power Factor 0.95

Note Abbreviations in column titles

P_LH - Power Leonards Hill
Q_LH - Reactive Leonards Hill
BN - BAN
ND - NODE
BR - Brewer
REG - Regulator – tap on sending side

BAN 11 22kV Feeder - Low Demand - 0.90pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.00	17.9	7.9	1.012	1.002	0.992	0.984	0.982	1.013	1.009	1.007	1.005	1.002	1.001	1.000	0.970	0.990
Sys-normal	0.5	-0.25	17.4	8.2	1.012	1.002	0.993	0.985	0.984	1.007	1.004	1.002	0.999	0.997	0.995	0.995	0.977	0.990
Sys-normal	1.0	-0.50	16.9	8.4	1.012	1.003	0.993	0.987	0.985	1.005	1.003	1.000	0.998	0.996	0.994	0.993	0.980	0.990
Sys-normal	1.5	-0.75	16.4	8.6	1.012	1.003	0.994	0.988	0.986	1.002	1.000	0.998	0.996	0.993	0.991	0.991	0.984	0.990
Sys-normal	2.0	-1.00	15.9	8.9	1.011	1.003	0.994	0.989	0.988	1.000	0.999	0.996	0.994	0.992	0.990	0.989	0.987	0.990
Sys-normal	2.5	-1.25	15.4	9.1	1.011	1.003	0.995	0.990	0.989	0.989	0.987	0.985	0.983	0.980	0.979	0.978	1.000	0.990
Sys-normal	3.0	-1.50	14.9	9.4	1.011	1.003	0.995	0.990	0.990	0.990	0.988	0.986	0.984	0.981	0.980	0.979	1.000	0.990
Sys-normal	3.5	-1.75	14.4	9.7	1.011	1.003	0.995	0.991	0.991	0.990	0.990	0.987	0.985	0.983	0.981	0.980	1.000	0.990
Sys-normal	4.0	-2.00	13.9	10.0	1.010	1.003	0.995	0.992	0.991	0.991	0.991	0.988	0.986	0.984	0.982	0.982	1.000	0.990

Table A3 High Feeder Demand, Generation Power Factor 0.90

Note Abbreviations in column titles

P_LH - Power Leonards Hill
Q_LH - Reactive Leonards Hill
BN - BAN
ND - NODE
BR - Brewer
REG - Regulator – tap on sending side

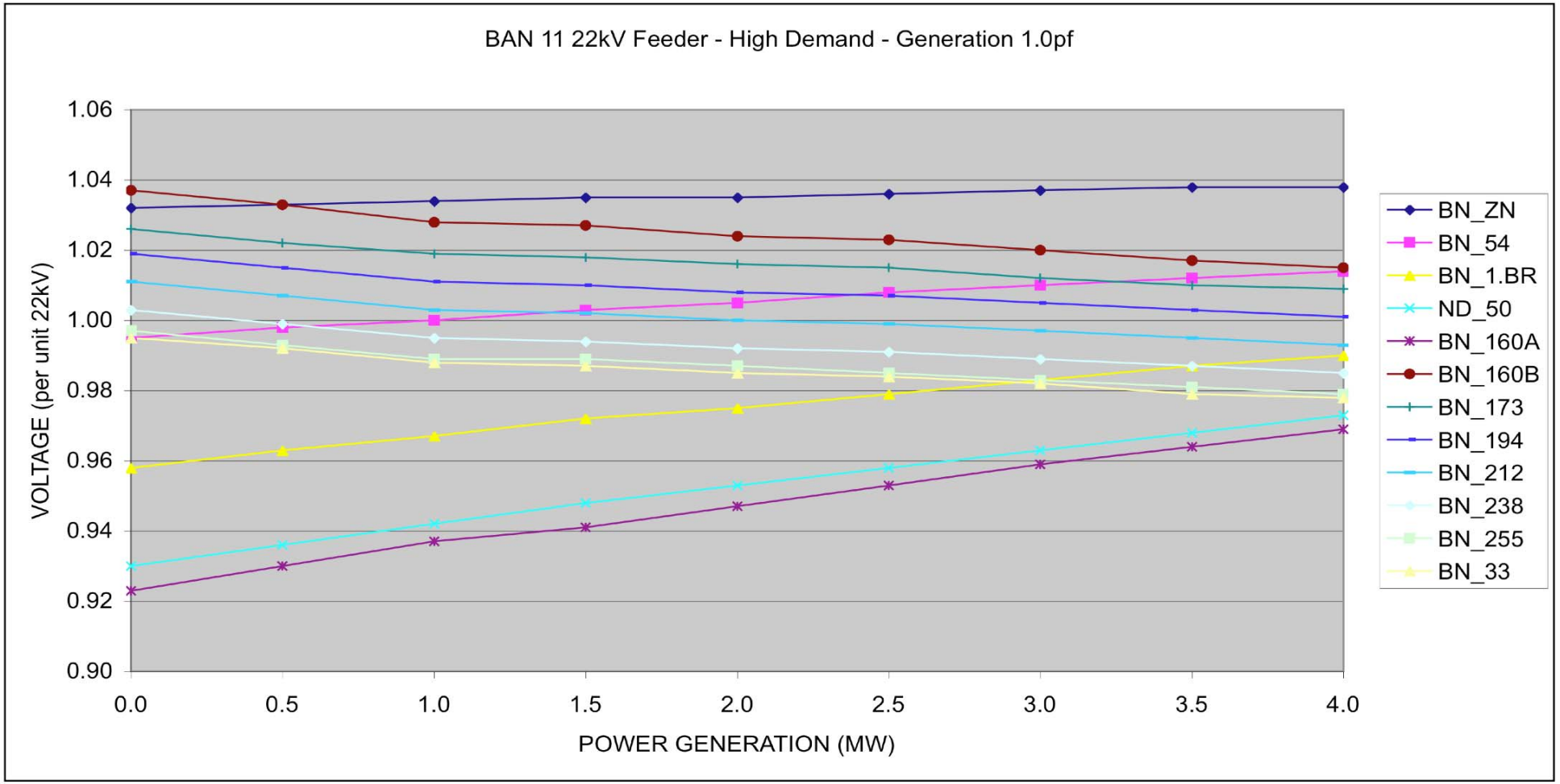

Figure A1

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer

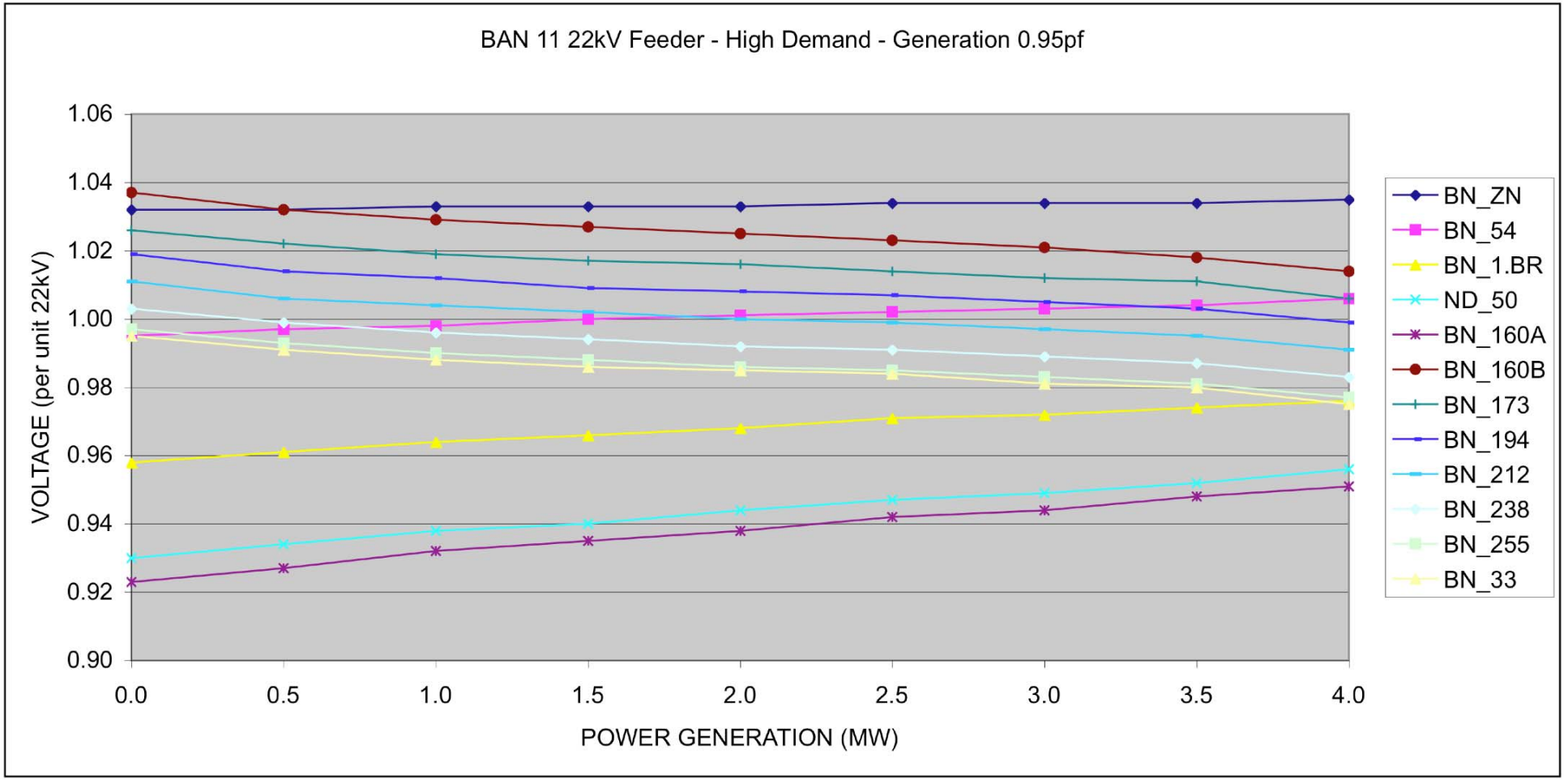

Figure A2

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer

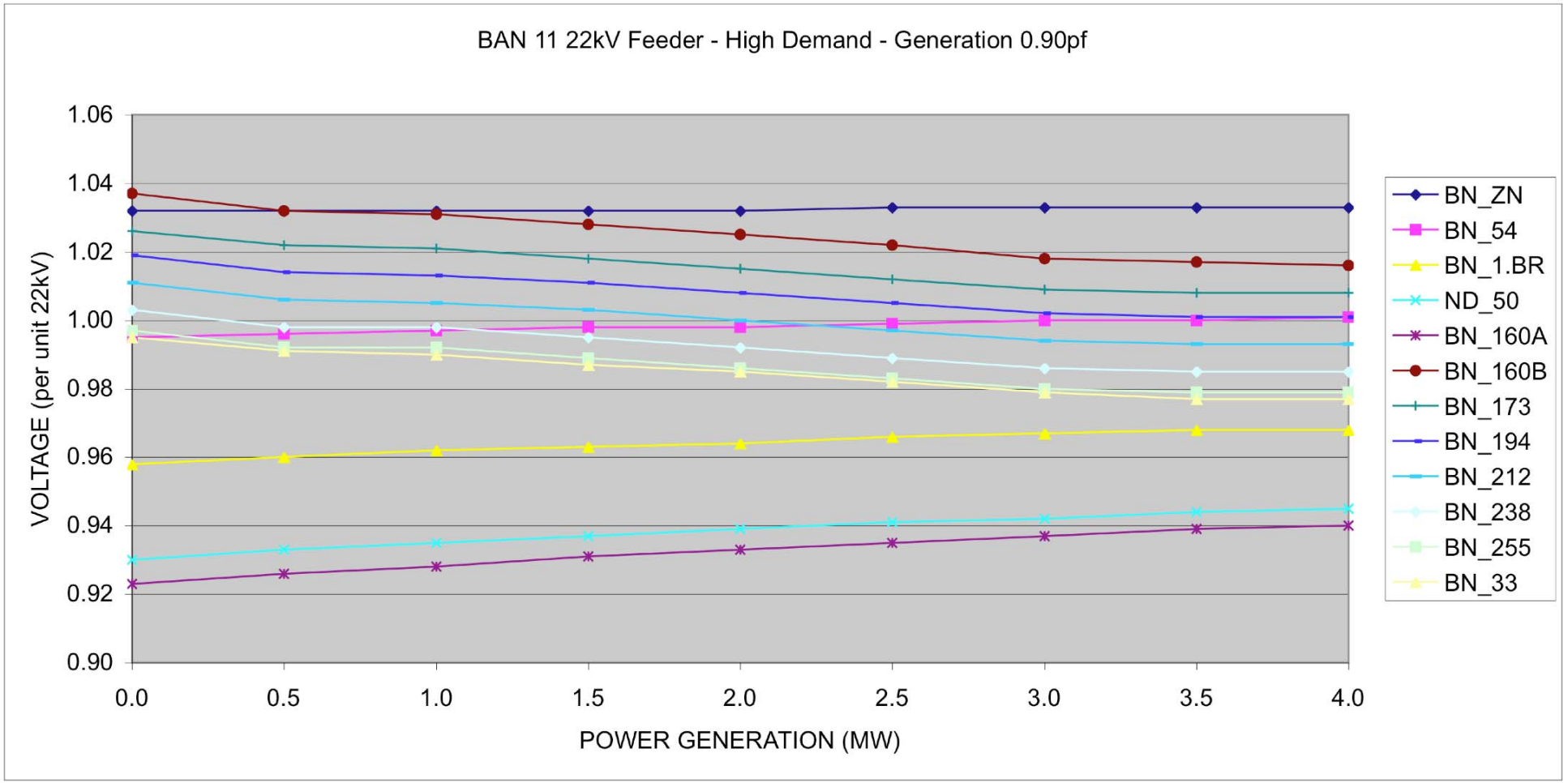

Figure A3

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer

Appendix B Low Load

Table B1 1.00 power factor
Table B2 0.95 power factor
Table B3 0.90 power factor

Figure B1 1.00 power factor
Figure B2 0.95 power factor
Figure B3 0.90 power factor

BAN 11 22kV Feeder - Low Demand - 1.0pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.0	17.9	7.9	1.012	1.002	0.992	0.984	0.982	1.013	1.009	1.007	1.005	1.002	1.001	1.000	0.970	0.990
Sys-normal	0.5	0.0	17.4	7.9	1.013	1.004	0.995	0.989	0.987	1.007	1.004	1.002	1.000	0.997	0.996	0.995	0.980	0.990
Sys-normal	1.0	0.0	16.9	7.9	1.013	1.006	0.998	0.993	0.992	1.007	1.005	1.002	1.000	0.998	0.996	0.995	0.985	0.990
Sys-normal	1.5	0.0	16.4	7.9	1.014	1.007	1.001	0.997	0.996	1.001	1.000	0.997	0.995	0.993	0.991	0.990	0.995	0.990
Sys-normal	2.0	0.0	15.9	7.9	1.014	1.009	1.004	1.001	1.001	1.000	1.000	0.997	0.995	0.993	0.991	0.990	1.000	0.990
Sys-normal	2.5	0.0	15.4	7.9	1.014	1.011	1.007	1.005	1.005	1.005	1.004	1.002	1.000	0.997	0.996	0.995	1.000	0.990
Sys-normal	3.0	0.0	14.9	7.9	1.015	1.012	1.010	1.009	1.009	1.009	1.009	1.007	1.004	1.002	1.000	1.000	1.000	0.990
Sys-normal	3.5	0.0	14.4	7.9	1.015	1.014	1.012	1.012	1.013	1.013	1.013	1.011	1.009	1.007	1.005	1.004	1.000	0.990
Sys-normal	4.0	0.0	14.0	7.9	1.016	1.015	1.015	1.016	1.017	1.017	1.018	1.016	1.013	1.011	1.009	1.009	1.000	0.990

Table B1 Low Feeder Demand, Generation Power Factor 1.00

BAN 11 22kV Feeder - Low Demand - 0.95pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.00	17.9	7.9	1.012	1.002	0.992	0.984	0.982	1.013	1.009	1.007	1.005	1.002	1.001	1.000	0.970	0.990
Sys-normal	0.5	-0.16	17.4	8.1	1.012	1.003	0.994	0.987	0.985	1.007	1.004	1.002	1.000	0.997	0.996	0.995	0.978	0.990
Sys-normal	1.0	-0.33	16.9	8.2	1.012	1.004	0.995	0.989	0.987	1.005	1.003	1.001	0.998	0.996	0.994	0.994	0.982	0.990
Sys-normal	1.5	-0.50	16.4	8.4	1.012	1.004	0.996	0.991	0.990	1.002	1.000	0.997	0.995	0.993	0.991	0.990	0.988	0.990
Sys-normal	2.0	-0.67	15.9	8.6	1.012	1.005	0.998	0.993	0.992	1.002	1.000	0.998	0.996	0.993	0.992	0.991	0.990	0.990
Sys-normal	2.5	-0.80	15.4	8.7	1.012	1.006	0.999	0.995	0.995	0.995	0.993	0.991	0.989	0.986	0.985	0.984	1.000	0.990
Sys-normal	3.0	-1.00	14.9	8.9	1.012	1.006	1.000	0.997	0.996	0.996	0.995	0.993	0.991	0.988	0.987	0.986	1.000	0.990
Sys-normal	3.5	-1.16	14.4	9.1	1.012	1.007	1.001	0.998	0.998	0.998	0.998	0.996	0.993	0.991	0.989	0.989	1.000	0.990
Sys-normal	4.0	-1.30	13.9	9.2	1.012	1.007	1.002	1.000	1.001	1.000	1.000	0.998	0.996	0.994	0.992	0.991	1.000	0.990

Table B2 Low Feeder Demand, Generation Power Factor 0.95

Note Abbreviations in column titles

P_LH - Power Leonards Hill
Q_LH - Reactive Leonards Hill
BN - BAN
ND - NODE
BR - Brewer
REG - Regulator – tap on sending side

BAN 11 22kV Feeder - Low Demand - 0.90pf

	Loading				Voltages (pu 22kV)													
Condition	**P_LH**	**Q_LH**	**P_BN**	**Q_BN**	**BN_ZN**	**BN_54**	**BN_1.BR**	**ND_50**	**BN_160A**	**BN_160B**	**BN_173**	**BN_194**	**BN_212**	**BN_238**	**BN_255**	**BN_33**	**TAP**	**TAP**
	MW	**MVAr**	**MW**	**MVAr**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**pu**	**REG_1**	**REG_2**
Sys-normal	0.0	0.00	17.9	7.9	1.012	1.002	0.992	0.984	0.982	1.013	1.009	1.007	1.005	1.002	1.001	1.000	0.970	0.990
Sys-normal	0.5	-0.25	17.4	8.2	1.012	1.002	0.993	0.985	0.984	1.007	1.004	1.002	0.999	0.997	0.995	0.995	0.977	0.990
Sys-normal	1.0	-0.50	16.9	8.4	1.012	1.003	0.993	0.987	0.985	1.005	1.003	1.000	0.998	0.996	0.994	0.993	0.980	0.990
Sys-normal	1.5	-0.75	16.4	8.6	1.012	1.003	0.994	0.988	0.986	1.002	1.000	0.998	0.996	0.993	0.991	0.991	0.984	0.990
Sys-normal	2.0	-1.00	15.9	8.9	1.011	1.003	0.994	0.989	0.988	1.000	0.999	0.996	0.994	0.992	0.990	0.989	0.987	0.990
Sys-normal	2.5	-1.25	15.4	9.1	1.011	1.003	0.995	0.990	0.989	0.989	0.987	0.985	0.983	0.980	0.979	0.978	1.000	0.990
Sys-normal	3.0	-1.50	14.9	9.4	1.011	1.003	0.995	0.990	0.990	0.990	0.988	0.986	0.984	0.981	0.980	0.979	1.000	0.990
Sys-normal	3.5	-1.75	14.4	9.7	1.011	1.003	0.995	0.991	0.991	0.990	0.990	0.987	0.985	0.983	0.981	0.980	1.000	0.990
Sys-normal	4.0	-2.00	13.9	10.0	1.010	1.003	0.995	0.992	0.991	0.991	0.991	0.988	0.986	0.984	0.982	0.982	1.000	0.990

Table B3 Low Feeder Demand, Generation Power Factor 0.90

Note Abbreviations in column titles

P_LH - Power Leonards Hill
Q_LH - Reactive Leonards Hill
BN - BAN
ND - NODE
BR - Brewer
REG - Regulator – tap on sending side

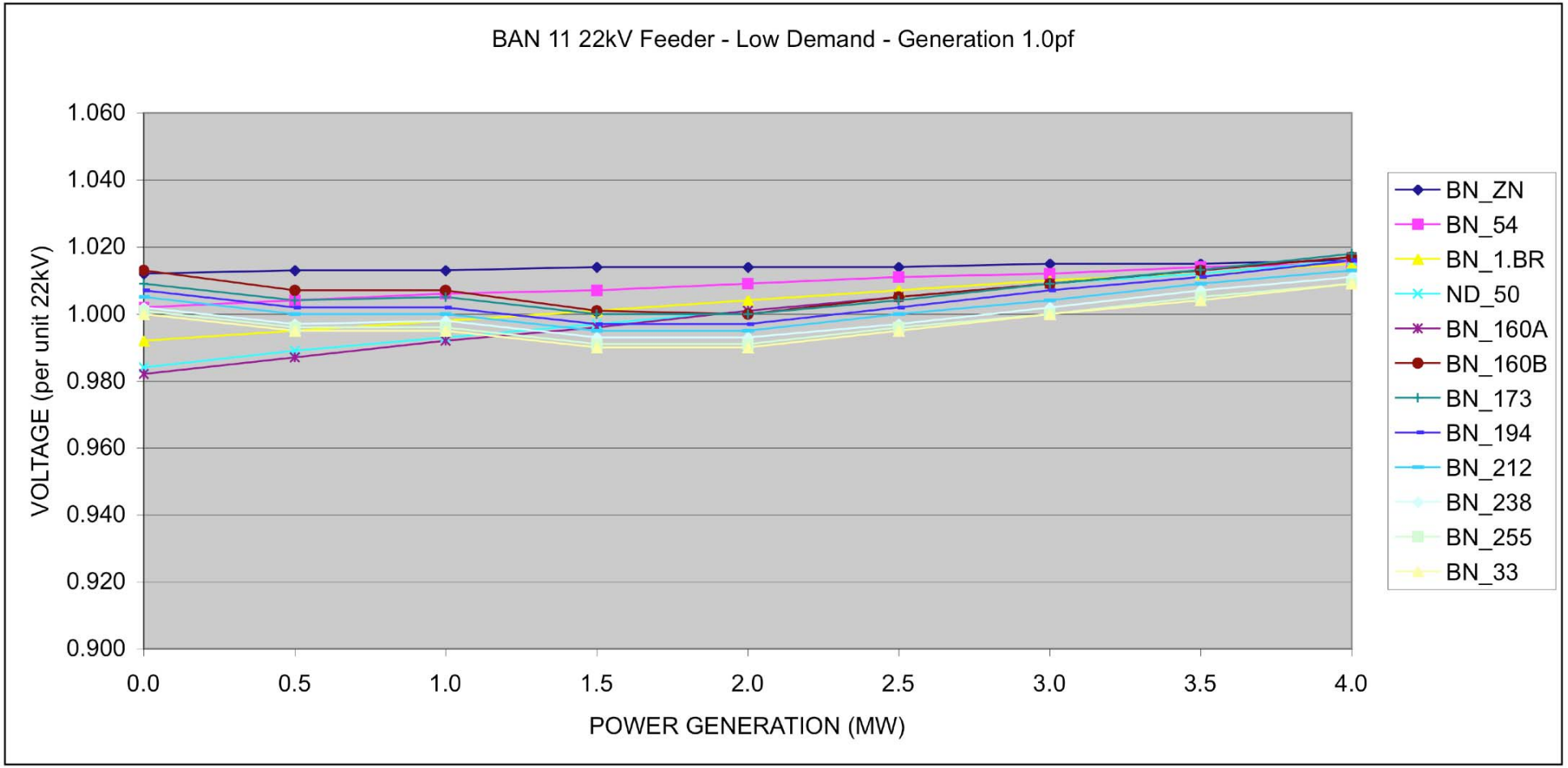

Figure B1

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer

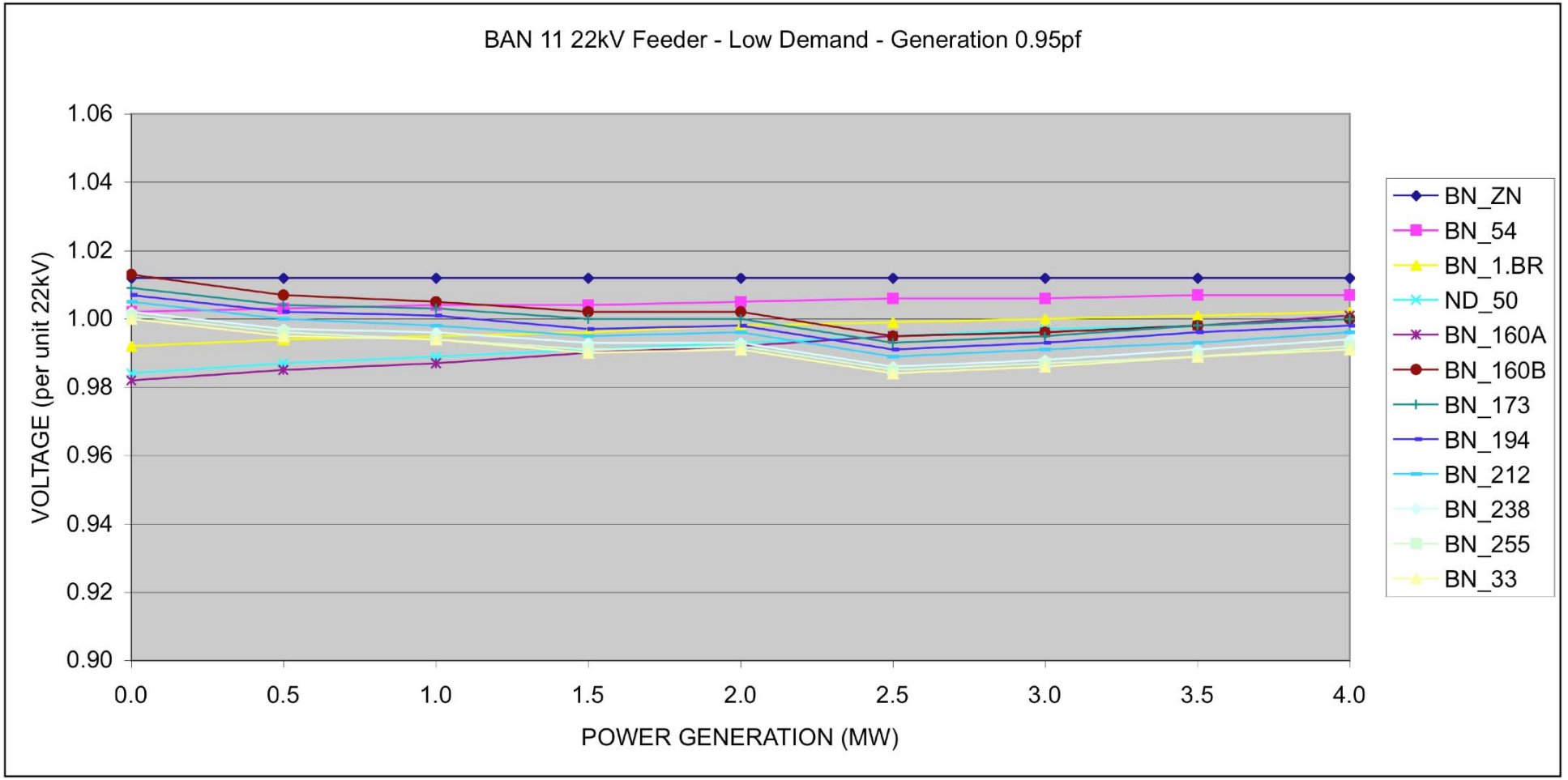

Figure B2

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer

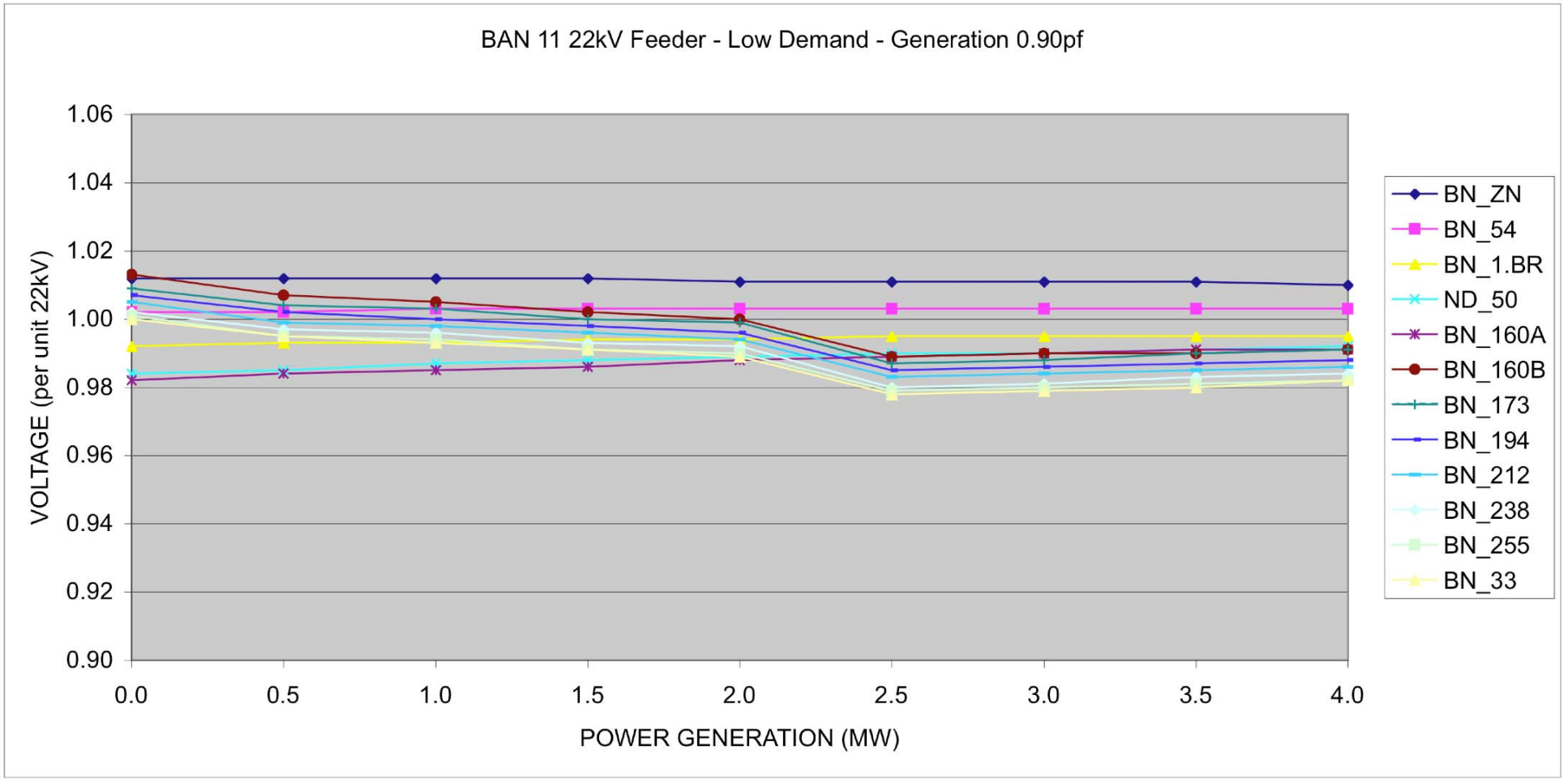

Figure B3

Note Abbreviations in legend titles
BN for BAN
ND for NODE
BR for Brewer