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CONNECTION ASSESSMENT & APPROVAL PROCESS

PRELIMINARY ASSESSMENT REPORT - Addendum

Applicant: EPCOR Power Development Corp.

Project: Kingsbridge Wind Park at Goderich

CAA ID No. 2002-081

*Consistent Information Set Department, and
Long Term Forecasts & Assessments Department*

FINAL Version

Date: 14th April 2005

Preliminary Assessment Report - Addendum

For the Kingsbridge Wind Park Project at Goderich

1. Introduction

EPCOR Power Development Corp. was recently awarded a contract to develop a 39.6MW wind-turbine generating facility under the Ontario Government's RFP for 300MW of Renewable Energy Supply. To meet the terms of this contract EPCOR plans to have the facility operational by 8th August 2005.

2. Proposed Arrangement

Diagram 1 shows the proposed incorporation arrangement for the new facility on to the 27.6kV busbar at Goderich TS.

Two dedicated 27.6kV circuits are to be installed to connect the two 'collection' substations, A & B, to the existing busbar at Goderich TS. These circuits are to occupy common structures over the final 10.5km section of their route into Goderich TS. A total of ten 1.8MW Vestas V80 wind-turbine generators are to be connected to Substation B through individual feeders with an average length of 5km. Substation A, which is to be located a further 17km from Substation B, is to be the collection point for twelve 1.8MW Vestas V80 wind-turbine generators. The average length of the connections on to the busbar at Substation A will also be 5km.

Each Vestas V80 wind-turbine is to be equipped with a series of automatically-switched capacitor banks that are intended to compensate for the reactive power drawn by the wind-turbine generator, so that the reactive power flow into its local 690V/27.6kV step-up transformer is maintained at approximately 0MVar.

Each Substation is to have a 4MVar shunt capacitor bank connected to it. In addition Substation A is to be equipped with a D-VAR device from American Superconductor with a continuous rating of +/- 2MVar and a short-term (1-second) overload rating of +/- 6MVar (3-times). This D-VAR device is to be connected to the 27.6kV busbar at Substation A via a dedicated 2.5MVA 480V/27.6kV step-up transformer.

3. IESO Requirements for Wind Projects Incorporated into LV Systems:

That the wind-turbine Project have the capability to control the voltage at the Point of Connection (in this case the 27.6kV busbar at Goderich TS), with the transformer tap-changers assumed locked and with a constant load at the TS (Goderich TS) -

- to within +/- 0.5% of the set point over the entire operational range of the wind-turbine generators, and
- with a reactive power injection at the 27.6kV busbar of at least 0MVar, when the wind-turbine generators are operating at their maximum output.

4. Assessment

In the absence of validated models for the wind-turbine generators that are to be installed on this Project, the IESO has limited its assessment primarily to a series of load flow studies of the proposed connection arrangement. In addition, some transient studies were performed using a conventional induction generator model.

Furthermore, because the IESO experienced difficulty in obtaining flows close to 0MVAR with the model that was provided, the analysis was therefore performed with the wind-turbine generators set at unity power factor.

The IESO has also assumed that the two existing 6.6MVAR capacitor banks at Goderich TS will continue to be deployed in accordance with the load level at Goderich TS.

Reactive Power Losses & Compensation

With the Kingsbridge Wind Park operating at full output (39.6MW), the reactive power losses were determined to be approximately as shown below:

<i>Reactive Power Losses</i>			
<i>Substation A: 21.6MW of Generation Capacity</i>		<i>Substation B: 18.0MW of Generation Capacity</i>	
Step-up Transformers	1.4MVAR	Step-up Transformers	1.2MVAR
5km Collection Circuits	0.4MVAR	5km Collection Circuits	0.4MVAR
27.5km Incorporation Circuit	5.2MVAR	10.5km Incorporation Circuit	1.5MVAR
<i>Total</i>	<i>7.0MVAR</i>	<i>Total</i>	<i>3.1MVAR</i>
<i>Combined Losses for the Entire Facility: 10.1MVAR</i>			

After allowing for the above-nominal voltages at Substations A & B, the expected output from the two 4MVAR (rated at 27.6kV) shunt capacitor banks that EPCOR is proposing to install will be approximately 9.6MVAR. Consequently, these capacitor banks, together with the +/- 2MVAR D-VAR device that it is proposed to install at Substation A, would be sufficient to compensate for these peak losses.

Furthermore, the proposed combination of the two capacitor banks and the D-VAR device is expected to meet the IESO's requirement of having the capability of injecting at least 0MVAR into the Goderich 27.6kV busbar whenever the Wind Park is operating at its maximum output.

Analytical Approach

The IESO adopted the following approach for its analysis:

- i. Establish a series of Reference Cases for specific loading conditions at Goderich TS, with the Kingsbridge Wind Park assumed to be operating at its peak output.

For each of these reference cases, both shunt capacitor banks associated with the wind project were assumed to be in-service and the D-VAR device was set at 0MVAR.

The transformer tap-changers were then allowed to move to produce a converged load flow solution.

This would provide a reference voltage for the 27.6kV busbar at Goderich TS together with a corresponding tap position for the transformer tap-changers.

The limits on the D-VAR device were then set to +2MVAR & -2MVAR and the load flow study was repeated with the transformer tap-changers locked.

These Reference Cases have been identified in Table 1. This Table also shows the operational status that was assumed for each of the two 6.6MVAR capacitor banks at Goderich TS for the respective load levels that were examined.

- ii. For each Reference Case, load flow studies were conducted with the Kingsbridge Wind Park operating at different output levels with different combinations of the 4MVAR shunt capacitor banks in-service, while maintaining the transformer tap-changers on the same positions.

The results from these studies have been summarised in Table 1.

4.1 Comments on the Study Results

- For each loading condition, the reference (target) voltage for the 27.6kV busbar at Goderich TS has been given at the end of the title entry.
- For those conditions in which the D-VAR reaches its maximum output, either +2MVAR or -2MVAR, the results have been shown shaded. Similarly, if the voltage at Goderich TS cannot be maintained at the specified target value, the results have also been shown shaded.
- In addition, the entries for those cases which resulted in terminal voltages at the wind-turbine generators that were 10% or more above their nominal voltages have been shown lightly shaded.

It is interesting to note that those cases involving high terminal voltages occurred when the D-VAR was producing MVARs and the 4MVAR capacitor bank connected to Substation A was also in-service.

- The results display a high level of consistency for each of the loading conditions that were assumed at Goderich TS. This indicates that once an appropriate tap position has been established for a particular loading condition at Goderich TS, the performance of the Wind Farm can be addressed independently.
- The results, showing only those operating condition that are considered to be viable, have been presented in Table 2.

This also shows the net reactive power injection from the Kingsbridge Wind Park into the 27.6kV busbar at Goderich TS.

- Table 3 provides a summary of the reactive power flows at Goderich TS for each of the 'viable' operating conditions, together with the reactive power losses that occur through the three step-down transformers.

These losses range from 0MVA_r, when the output of the Wind Park matches the load at Goderich TS and there are no power flows from the 115kV system, to a maximum of 4.1MVA_r whenever the output of the Wind Park is zero and the peak load at Goderich TS of approximately 40MW is supplied entirely from the 115kV system.

- Consequently, in order for the voltage on the 27.6kV busbar at Goderich TS to be maintained at a constant value over the entire output range of the Wind Park, the Wind Park would have to supply not only the reactive power losses from its connection system, but would also have to compensate for the reactive power losses occurring through the transformers. These losses will vary in response to the changing output from the Wind Park which will directly affect the transfers that occur through the transformers.

This is clearly demonstrated in Table 2 which shows that one of the 4MVA_r capacitor banks is required to be in-service even when the output of the Wind Park is zero and the associated losses on its collection system are also zero. Under these conditions, when all of the load at Goderich TS is being supplied from the 115kV system, the sole purpose of the capacitor bank is then to supply the losses through the transformers.

- The results summarised in Table 2 therefore suggest that with the capacitor banks deployed as indicated and with the D-VAR device controlling the voltage at Goderich TS, the output of the Wind Park could vary throughout its entire operating range without requiring any change in the tap-positions of the transformers.

4.2 Response to Changes in the Load at Goderich TS

One of the primary objectives of the reactive power compensation facilities to be installed on the Kingsbridge Wind Park is to minimise any additional operation of the transformer tap-changers at Goderich TS in response to variations in the output of the Wind Park by controlling the voltage at Goderich TS.

However, the voltage at Goderich TS will vary not only in response to changes in the output from the Wind Park but also to changes in the load supplied from Goderich TS. Since the control scheme for the Wind Park will not be able to distinguish between the cause of the change in voltage (i.e. the output from the Wind Park versus the actual load at Goderich TS) there is therefore a concern that the duty imposed on the tap-changers and that on the control scheme for the Wind Park will not be distributed equitably. Furthermore, since the response of the control scheme for the reactive compensation is expected to be much faster than that of the tap-changers, it will likely have the greater influence with respect to controlling the voltage at Goderich TS.

The control scheme for the Wind Park should therefore include a feature that will allow movement of the tap-changers to occur whenever the output of the D-VAR device approaches either extreme of its normal operating range. The intent would be to ensure that under normal operating conditions, the output from the D-VAR device is maintained within the range of approximately +/- 1 MVA_r.

4.3 Recommendations

Rather than allowing the D-VAR device to control the switching of the 4MVAR shunt capacitor banks, it is recommended that consideration be given to switching the capacitor banks in response to the actual output of the Wind Park so as to directly compensate for the reactive power losses on both the 27.6kV connection system and through the transformers at Goderich TS.

This would then leave the D-VAR available to control the voltage on the 27.6kV busbar at Goderich TS.

<i>Suggested Output Levels for the Deployment of the 4MVAR Capacitor Banks</i>		
<i>Output of the Wind Park</i>	0% to 85% (34MW)	One 4MVAR capacitor bank in-service
	Above 85%	Both 4MVAR capacitor banks in-service

In order to limit the effect of circulating reactive power and to simplify the deployment of the capacitor banks, while also minimising the high voltages on the terminals of the generating units, it is also recommended that consideration be given to terminating both of the circuits from Goderich TS on to Substation B and locating both capacitor banks on this busbar. In addition, if it is confirmed that dynamic voltage support is required for that part of the system associated with Substation A, in order for the generating facilities to satisfy the Low-Voltage Ride-Through requirements, then consideration could be given to relocating the D-VAR device to this common 27.6kV busbar at Substation B, as shown in Diagram 2.

4.4 Voltage Decline Study

The largest voltage decline would be expected to occur in response to the loss of the connection to Substation A for the condition when reactive power is being injected into the system, pre-contingency. Since this contingency would result in the loss of the D-VAR device, it would therefore be unable to provide post-contingency support.

From Table 1, with the load at Goderich TS at 80% of its peak value and with only a single 6.6MVAR capacitor bank in-service, the reactive power flow into Goderich TS is shown to be 2.8MVAR for the following condition:

- with the Wind Park operating at 80% of its peak output,
- with the 4MVAR capacitor at Substation A in-service, and
- with the D-VAR at its maximum continuous output of 2MVAR.

With the loads at Goderich TS represented as constant-MVA, the maximum post-contingency voltage decline, prior to tap-changer action, for the loss of the connection to Substation A, was only 2.5%. This would be well within the IESO's 10% criterion (with voltage dependent loads) for a 'system' contingency.

4.5 Transient Analysis

In the absence of validated dynamic models for the Vestas wind-turbine generators, the IESO has performed transient studies for a three-phase fault on the T5 230/115kV auto-transformer at Seaforth TS, using a conventional induction generator model.

The model, together with the data that were used in the transient studies, is shown in Diagram 3.

As noted in the Diagram, the saturation factors that were supplied by Vestas appear high. However, while these values were used in all of the analysis reported in this Addendum, an additional study was performed using the alternative values that have been indicated in the Diagram. The results obtained from this study, though similar, were marginally inferior.

The principal condition that was studied in the transient analysis corresponded to a peak load of 37.8MW at Goderich TS, with the Wind Park operating at its maximum output of 39.6MW.

Without the D-VAR Device

The results shown in Diagram 4 are for the condition without the D-VAR device in-service. This shows minimum voltages of 0.018 pu and 0.006 pu at the terminals of the wind-turbine generators connected to Substations A & B, respectively. Furthermore, while the terminal voltages for the wind-turbines associated with Substation B appear to recover following clearance of the fault, those for the wind-turbine generators associated with Substation A are shown to decline.

Diagram 5 shows the results for the same study conditions, but with the study period extended to 5-seconds. This shows the continued decline in the terminal voltage of the wind-turbine generators associated with Substation A to a value of approximately 0.4 pu. It also shows that this decline is affecting the performance of those wind-turbine generators associated with Substation B. While their terminal voltage appeared to recover in the previous study, this extended study shows their terminal voltage falling to a value of approximately 0.74 pu after 5-seconds.

Diagram 6 shows the results for the same study conditions, but with the output of those wind-turbine generators connected to Substation A limited to 50% of their maximum output (i.e. to 10.8MW). No similar restriction was assumed for the wind-turbine generators connected to Substation B.

These results show that, with the D-VAR device out-of-service, the terminal voltages of the wind-turbine generators would be expected to recover following clearance of the fault if the output of those wind-turbine generators connected to Substation A were to be restricted to 50%.

With the D-VAR Device

Diagram 7 shows the results for the same fault condition but with the D-VAR device assumed to be in-service. This shows an improvement in the minimum voltages experienced at the terminals of the wind-turbine generators, particularly for those generators associated with Substation A (to which the D-VAR device is connected). For those wind-turbine generators associated with Substation A, the minimum voltage is shown as 0.131 pu, while that for those wind-turbine generators associated with Substation B is only 0.025 pu. However, this would be an improvement over the 0.006 pu value obtained without the D-VAR device.

Once the fault is cleared, the voltages for both groups of wind-turbine generators show an acceptable recovery. After 1.4-seconds the terminal voltages of those wind-turbine generators associated with Substation A are shown to have recovered to 0.94 pu of nominal, while those associated with Substation B are shown to have recovered to a 0.92 pu.

Diagram 8 shows the performance of the D-VAR device during the study period. Its initial output is shown as -1MVAR, which increases to approximately +3MVAR upon application of the fault. Once the fault is cleared, the output of the D-VAR device peaks at approximately 6.6MVAR, declining to approximately 6.0MVAR at the end of the 1.4-second study period.

Comments

While the performance of the Vestas wind-turbine generators is expected to be superior to that obtained using a conventional induction generator model, the studies that have been performed appear to support the requirement to install a D-VAR device not only for the control of the voltage at Goderich TS but also to aid the recovery of the post-contingency voltages at the wind-turbine generators following a fault.

5. Conclusions

The analysis that has been performed has shown that, subject to the following, the proposed Kingsbridge Wind Park should have no adverse impact on the IESO-controlled grid or on the performance of the existing Hydro One facilities at Goderich TS, while also satisfying the IESO's requirements as detailed in Section 3:

- implementation of an appropriate strategy for deploying the 4MVAR capacitor banks to provide compensation for the reactive power losses of the Wind Park, and
- the installation of suitable controls on the D-VAR device so that it responds to an approximation of the target voltage at the 27.6kV busbar at Goderich TS that is used by the TCX relay for controlling the operation of the transformer tap-changers at Goderich TS.

[Note: With the Wind Park in operation, the input to the TCX relay will need to be the summated loading on the individual feeders supplying the loads at Goderich TS, and not the summated transfers through the three auto-transformers. This information will need to be made available to the control scheme for the Wind Park.]

Details of the proposed control scheme should be submitted to Hydro One, with a copy to the IESO, as soon as possible to allow for comments and possible revisions to the scheme prior to its implementation.

- Since the wind-turbine generators to be installed at the Kingsbridge Wind Park are to be equipped with the AGO4 option, they are to have the capability of remaining connected during periods when the voltage is less than 50% of nominal for up to 200 milliseconds. They are therefore expected to meet the IESO's requirement that the wind-turbine generators of the Kingsbridge Wind Park should not trip for any faults that are external to their connection on to the 27.6kV busbar at Goderich TS, or for faults that do not result in the wind farm's isolation due to the system configuration.

6. Increased Duty on the Tap-changers at Goderich TS

One of the primary concerns of both Hydro One and the IESO has been the possibility that the Kingsbridge Wind Park could increase the number of operations of the tap-changers at Goderich TS.

However, the results from the analysis suggest that with appropriate control of the D-VAR device, the Kingsbridge Wind Park should not increase this duty and could reduce it.

Monitoring

In order to establish whether the Kingsbridge Wind Park has any affect on the tap-changers' performance, Hydro One is intending to monitor the number of tap-changer operations before and after the Wind Park is placed in-service. In addition, the following monitoring is to be provided by EPCOR:

- the status of the shunt capacitor banks to be installed as part of the Kingsbridge Project, and
- the output of the D-VAR device.

Assurance from EPCOR Power Development Corp.

EPCOR has provided an assurance that should the Kingsbridge Wind Park result in a material increase in the number of tap-changer operations once it is placed in-service, then appropriate measures will be implemented within a period acceptable to Hydro One so that they do not exceed the present level.

7. Provision of Modelling Data

Suitable models for the wind-turbine generators, together with all necessary supporting evidence to validate these models, are to be submitted to the IESO as soon as possible and no later than six months after the initial in-service date.

In the absence of suitable data, the IESO has performed studies using a conventional induction generator model. These studies indicate that with the D-VAR device in-service, the performance of the Wind Park should be acceptable. However, should subsequent operational experience indicate problems, then the IESO reserves the right to limit the output from the Wind Park until suitable remedial measures can be implemented.

Furthermore, since the D-VAR device has been shown to be critical to the recovery of the post-contingency voltages at the Wind Park, the IESO requires the output from those facilities connected to Substation A to be limited to a maximum of 50% of their peak output whenever the D-VAR device is unavailable.

8. Generation Rejection

Since the maximum output that the Kingsbridge Wind Park will be capable of delivering will be approximately the same as the peak load at Goderich TS, there are not expected to be any net transfers from the Wind Park to the IESO-controlled grid during peak load periods.

Consequently, while there is no immediate requirement for the Kingsbridge Wind Park to participate in the Bruce Special Protection System, the IESO reserves the right to include the Kingsbridge Wind Park in the Scheme should any future developments in the area cause this situation to change.

9. Summary of the IESO's Requirements

The IESO's requirements have been summarised below:

IESO's requirements for the connection of the Kingsbridge Wind Park

- Install a scheme to control the 27.6kV busbar voltage at Goderich TS within the same range used to control the operation of the transformer tap-changers.

This scheme is to include the capability of initiating operation of the transformer tap-changers whenever the output of the D-VAR device approaches either extreme of its normal operating range.

Details of the control scheme are to be provided to Hydro One as soon as possible to allow for revisions to be incorporated prior to the Wind Park being placed in-service.

- Provide facilities to ensure that the Wind Park has the capability of injecting reactive power of at least 0MVAR into the 27.6kV busbar at Goderich TS when the wind-turbine generators are operating at their maximum output.
- Restrict the output from the wind-turbine generators connected to Substation A to within 50% of their peak output whenever the D-VAR device is unavailable.
- The wind-turbine generators of the Kingsbridge Wind Park are required to remain in-service for any faults that are external to their connection on to the 27.6kV busbar at Goderich TS, or for any faults that do not result in the wind farm's isolation due to its connection arrangement.
- Provide suitable models together with appropriate validation for the wind-turbine generators as soon as possible and no later than six months following the initial in-service date.
- In addition to the monitoring requirements specified in the Market Rules, the following monitoring is also to be provided:
 - the status of the shunt capacitor banks to be installed as part of the Kingsbridge Project, and
 - the output of the D-VAR device.
- Should the Wind Park materially increase the duty on the transformer tap-changers at Goderich TS, then measures are to be implemented within a period acceptable to Hydro One so that the number of operations do need exceed the present level.

10. Customer Impact Assessment

Hydro One Networks has concluded that, subject to meeting the IESO's requirements, this Project will have no adverse impact on any of the customers in the area and that a detailed Customer Impact Assessment will not be required.

11. Notification of Approval of the Connection Proposal

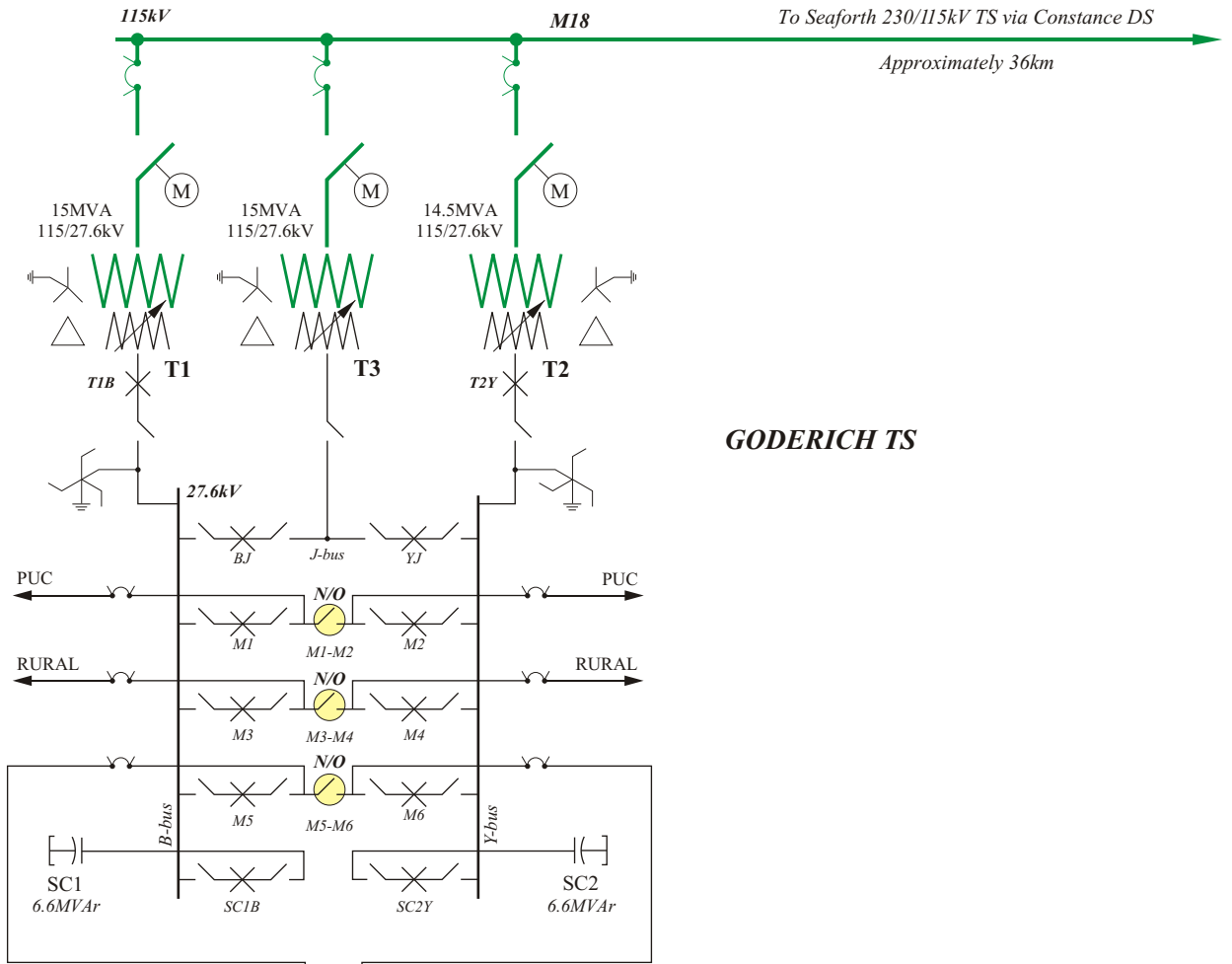
Subject to EPCOR Power Development Corp. meeting all of the IESO's requirements as detailed in Section 9 of this Report, it is recommended that a Notification of Approval of the Connection Proposal be issued for this Project.

TABLE 1		Results from the Load Flow Studies							
Generation Output (at unity power factor)		27.6kV Voltage at Goderich TS		Output of D-VAR	Development connected to Substation A		Development connected to Substation B		
					Cap. Bank	MVAR Flow (from Goderich TS)	Cap. Bank	MVAR Flow (from Goderich TS)	
A. Peak Load Condition at Goderich TS				37.8MW : 18.3MVar		Both 6.6MVar capacitor banks in-service (Ref Voltage = 1.044)			
100%	39.6MW	1.031 pu		2.0MVar	4MVar	0.1MVar	0MVar	3.0MVar	
		1.024 pu		2.0MVar	0MVar	5.8MVar	4MVar	-1.4MVar	
		Ref.	1.044 pu	0.1MVar	4MVar	2.0MVar	4MVar	-1.6MVar	
80%	31.6MW	1.044 pu		2.0MVar	4MVar	-2.8MVar	0MVar	2.0MVar	
		1.038 pu		2.0MVar	0MVar	3.2MVar	4MVar	-2.7MVar	
		1.044 pu		-2.0MVar	4MVar	1.3MVar	4MVar	-2.8MVar	
50%	19.8MW	1.044 pu		0.6MVar	4MVar	-3.3MVar	0MVar	0.7MVar	
		1.044 pu		1.1MVar	0MVar	1.3MVar	4MVar	-3.8MVar	
		1.027 pu		2.0MVar	0MVar	-0.1MVar	0MVar	0.7MVar	
0%	0MW	1.038 pu		2.0MVar	4MVar	-6.8MVar	0MVar	-0.1MVar	
		1.037 pu		2.0MVar	0MVar	-2.2MVar	4MVar	-4.5MVar	
		1.044 pu		-1.3MVar	4MVar	-3.2MVar	4MVar	-4.5MVar	
		1.015 pu		2.0MVar	0MVar	-2MVar	0MVar	-0.1MVar	
B. 80% Peak Load Condition at Goderich TS				30.2MW : 14.6MVar		Only One 6.6MVar capacitor bank in-service (Ref Voltage= 1.045)			
100%	39.6MW	1.032 pu		2.0MVar	4MVar	0.1MVar	0MVar	3.0MVar	
		1.026 pu		2.0MVar	0MVar	5.8MVar	4MVar	-1.4MVar	
		Ref.	1.045 pu	0.0MVar	4MVar	2.0MVar	4MVar	-1.7MVar	
80%	31.6MW	1.045 pu		2.0MVar	4MVar	-2.8MVar	0MVar	2.0MVar	
		1.040 pu		2.0MVar	0MVar	3.1MVar	4MVar	-2.7MVar	
		1.049 pu		-2.0MVar	4MVar	1.3MVar	4MVar	-2.8MVar	
50%	19.8MW	1.045 pu		-0.1MVar	4MVar	-2.8MVar	0MVar	0.7MVar	
		1.045 pu		0.4MVar	0MVar	1.8MVar	4MVar	-3.9MVar	
		1.031 pu		2.0MVar	0MVar	-0.1MVar	0MVar	0.7MVar	
0%	0MW	1.044 pu		2.0MVar	4MVar	-6.0MVar	0MVar	-0.1MVar	
		1.044 pu		2.0MVar	0MVar	-1.4MVar	4MVar	-4.5MVar	
		1.023 pu		2.0MVar	0MVar	-2.0MVar	0MVar	-0.1MVar	
		1.047 pu		-2.0MVar	4MVar	-2.7MVar	4MVar	-4.6MVar	

<i>Table 1 - continued</i>		<i>Results from the Load Flow Studies</i>					
<i>C. Minimum Load Condition at Goderich TS</i>			<i>20MW : 9.7MVar</i>		<i>Both 6.6MVar capacitor bank out of service (Ref Voltage = 1.045)</i>		
<i>Generation Output (at unity power factor)</i>	<i>27.6kV Voltage at Goderich TS</i>		<i>Output of D-VAR</i>	<i>Development connected to Substation A</i>		<i>Development connected to Substation B</i>	
				<i>Cap. Bank</i>	<i>MVar Flow (from Goderich TS)</i>	<i>Cap. Bank</i>	<i>MVar Flow (from Goderich TS)</i>
100% 39.6MW	1.032 pu		2.0MVar	4MVar	0.1MVar	0MVar	3.0MVar
	1.026 pu		2.0MVar	0MVar	5.8MVar	4MVar	-1.4MVar
	Ref.	1.045 pu	0.1MVar	4MVar	2.0MVar	4MVar	-1.6MVar
80% 31.6MW	1.044 pu		2.0MVar	4MVar	-1.8MVar	0MVar	2.0MVar
	1.043 pu		2.0MVar	0MVar	2.7MVar	4MVar	-2.7MVar
	1.050 pu		-2.0MVar	4MVar	1.3MVar	4MVar	-2.8MVar
50% 19.8MW	1.045 pu		-0.8MVar	4MVar	-1.6MVar	0MVar	0.7MVar
	1.045 pu		-0.3MVar	0MVar	3.3MVar	4MVar	-3.8MVar
	1.035 pu		2.0MVar	0MVar	-0.1MVar	0MVar	0.7MVar
0% 0MW	1.045 pu		0.3MVar	4MVar	-4.7MVar	0MVar	-0.1MVar
	1.045 pu		0.5MVar	0MVar	-0.2MVar	4MVar	-4.5MVar
	1.032 pu		2.0MVar	0MVar	-2.2MVar	0MVar	-0.1MVar
<i>D. Minimum Load Condition at Goderich TS</i>			<i>20MW : 9.7MVar</i>		<i>Only One 6.6MVar capacitor bank in service (Ref Voltage = 1.045)</i>		
100% 39.6MW	1.033 pu		2.0MVar	4MVar	0.1MVar	0MVar	3.0MVar
	1.027 pu		2.0MVar	0MVar	5.8MVar	4MVar	-1.4MVar
	Ref.	1.045 pu	0.1MVar	4MVar	2.0MVar	4MVar	-1.7MVar
80% 31.6MW	1.044 pu		2.0MVar	4MVar	-1.8MVar	0MVar	2.0MVar
	1.043 pu		2.0MVar	0MVar	2.7MVar	4MVar	-2.7MVar
	1.049 pu		-2.0MVar	4MVar	1.3MVar	4MVar	-2.8MVar
50% 19.8MW	1.045 pu		-0.7MVar	4MVar	-1.6MVar	0MVar	0.7MVar
	1.045 pu		-0.2MVar	0MVar	2.3MVar	4MVar	-3.9MVar
	1.035 pu		2.0MVar	0MVar	-0.1MVar	0MVar	0.7MVar
0% 0MW	1.045 pu		0.5MVar	4MVar	-4.8MVar	0MVar	-0.1MVar
	1.045 pu		0.6MVar	0MVar	-0.3MVar	4MVar	-4.5MVar
	1.031 pu		2.0MVar	0MVar	-2.2MVar	0MVar	-0.0MVar

TABLE 2		Results for only the 'Viable' Operating Conditions							
Generation Output (at unity power factor)		27.6kV Voltage at Goderich TS		Output of D-VAR	Development connected to Substation A		Development connected to Substation B		Net Injection from Wind Park into Goderich TS
					Cap. Bank	MVAr Flow (from Goderich TS)	Cap. Bank	MVAr Flow (from Goderich TS)	
A. Peak Load Condition at Goderich TS					37.8MW : 18.3MVAr		Both 6.6MVAr capacitor banks in-service		(Ref Voltage = 1.044)
100%	39.6MW	Ref.	1.044 pu	0.1MVAr	4MVAr	2.0MVAr	4MVAr	-1.6MVAr	-0.4MVAr
80%	31.6MW		1.044 pu	2.0MVAr	4MVAr	-2.8MVAr	0MVAr	2.0MVAr	0.8MVAr
			1.044 pu	-2.0MVAr	4MVAr	1.3MVAr	4MVAr	-2.8MVAr	1.5MVAr
50%	19.8MW		1.044 pu	0.6MVAr	4MVAr	-3.3MVAr	0MVAr	0.7MVAr	2.6MVAr
			1.044 pu	1.1MVAr	0MVAr	1.3MVAr	4MVAr	-3.8MVAr	2.5MVAr
0%	0MW		1.044 pu	-1.3MVAr	4MVAr	-3.2MVAr	4MVAr	-4.5MVAr	7.7MVAr
B. 80% Peak Load Condition at Goderich TS					30.2MW : 14.6MVAr		Only One 6.6MVAr capacitor bank in-service		(Ref Voltage = 1.045)
100%	39.6MW	Ref.	1.045 pu	0.0MVAr	4MVAr	2.0MVAr	4MVAr	-1.7MVAr	-0.3MVAr
80%	31.6MW		1.045 pu	2.0MVAr	4MVAr	-2.8MVAr	0MVAr	2.0MVAr	0.8MVAr
50%	19.8MW		1.045 pu	-0.1MVAr	4MVAr	-2.8MVAr	0MVAr	0.7MVAr	2.1MVAr
			1.045 pu	0.4MVAr	0MVAr	1.8MVAr	4MVAr	-3.9MVAr	2.1MVAr
0%	0MW		1.044 pu	2.0MVAr	4MVAr	-6.0MVAr	0MVAr	-0.1MVAr	6.1MVAr
			1.044 pu	2.0MVAr	0MVAr	-1.4MVAr	4MVAr	-4.5MVAr	5.9MVAr
C. Minimum Load Condition at Goderich TS					20MW : 9.7MVAr		With One or Neither of the 6.6MVAr cap banks in- service		(Ref Voltage = 1.045)
100%	39.6MW	Ref.	1.045 pu	0.1MVAr	4MVAr	2.0MVAr	4MVAr	-1.6MVAr	-0.4MVAr
80%	31.6MW		1.044 pu	2.0MVAr	4MVAr	-1.8MVAr	0MVAr	2.0MVAr	-0.2MVAr
50%	19.8MW		1.045 pu	-0.8MVAr	4MVAr	-1.6MVAr	0MVAr	0.7MVAr	0.9MVAr
			1.045 pu	-0.3MVAr	0MVAr	3.3MVAr	4MVAr	-3.8MVAr	0.5MVAr
0%	0MW		1.045 pu	0.3MVAr	4MVAr	-4.7MVAr	0MVAr	-0.1MVAr	4.8MVAr
			1.045 pu	0.5MVAr	0MVAr	-0.2MVAr	4MVAr	-4.5MVAr	4.7MVAr

TABLE 3		Reactive Power Losses Through the Transformers at Goderich TS							
Generation Output (at unity power factor)	Output of D-VAR	Reactive Power Flows into Goderich TS				Output of Capacitors at Goderich TS	Goderich Transformers		
		From Substation A	From Substation B	Net Injection from Wind Park	From 115kV System		Net Power Flow	Reactive Power Losses	
A. Peak Load Condition at Goderich TS		37.8MW : 18.3MVar				Both 6.6MVar capacitor banks in-service		(Ref Voltage = 1.044)	
100%	39.6MW	0.1MVar	-2.0MVar	1.6MVar	-0.4MVar	4.7MVar	14.4MVar	-1.8MW	0.4MVar
80%	31.6MW	2.0MVar	2.8MVar	-2.0MVar	0.8MVar	3.7MVar	14.4MVar	6.2MW	0.6MVar
50%	19.8MW	0.6MVar	3.3MVar	-0.7MVar	2.6MVar	2.2MVar	14.4MVar	18.0MW	0.9MVar
0%	0MW	-1.3MVar	3.2MVar	4.5MVar	7.7MVar	0.3MVar	14.4MVar	37.8MW	4.1MVar
B. 80% Peak Load Condition at Goderich TS		30.2MW : 14.6MVar				Only One 6.6MVar capacitor bank in-service		(Ref Voltage = 1.045)	
100%	39.6MW	0.0MVar	-2.0MVar	1.7MVar	-0.3MVar	8.5MVar	7.2MVar	-9.4MW	0.8MVar
80%	31.6MW	2.0MVar	2.8MVar	-2.0MVar	0.8MVar	7.1MVar	7.2MVar	-1.4MW	0.5MVar
50%	19.8MW	-0.1MVar	2.8MVar	-0.7MVar	2.1MVar	5.9MVar	7.2MVar	10.4MW	0.6MVar
0%	0MW	2.0MVar	6.0MVar	0.1MVar	6.1MVar	3.3MVar	7.2MVar	30.2MW	2.0MVar
C. Minimum Load Condition at Goderich TS		20MW : 9.7MVar				With One or Neither of the 6.6MVar cap banks in- service		(Ref Voltage = 1.045)	
100%	39.6MW	0.1MVar	-2.0MVar	1.6MVar	-0.4MVar	11.4MVar	0.0MVar	-19.6MW	1.3MVar
80%	31.6MW	2.0MVar	1.8MVar	-2.0MVar	-0.2MVar	2.9MVar	7.2MVar	-11.6MW	0.2MVar
50%	19.8MW	-0.8MVar	1.6MVar	-0.7MVar	0.9MVar	8.8MVar	0.0MVar	0.2MW	0.0MVar
0%	0MW	0.3MVar	4.7MVar	0.1MVar	4.8MVar	6.0MVar	0.0MVar	20.0MW	1.1MVar

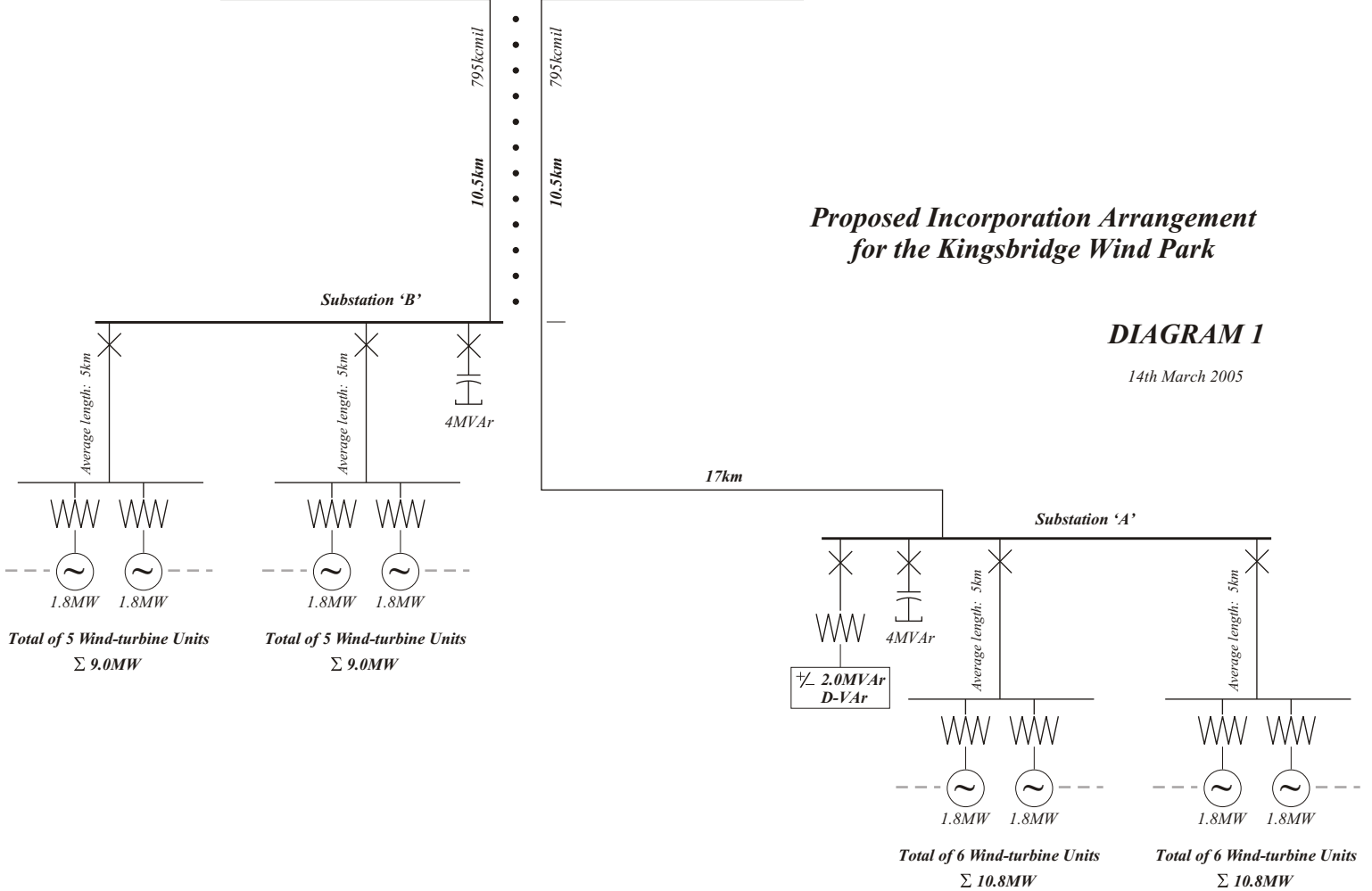


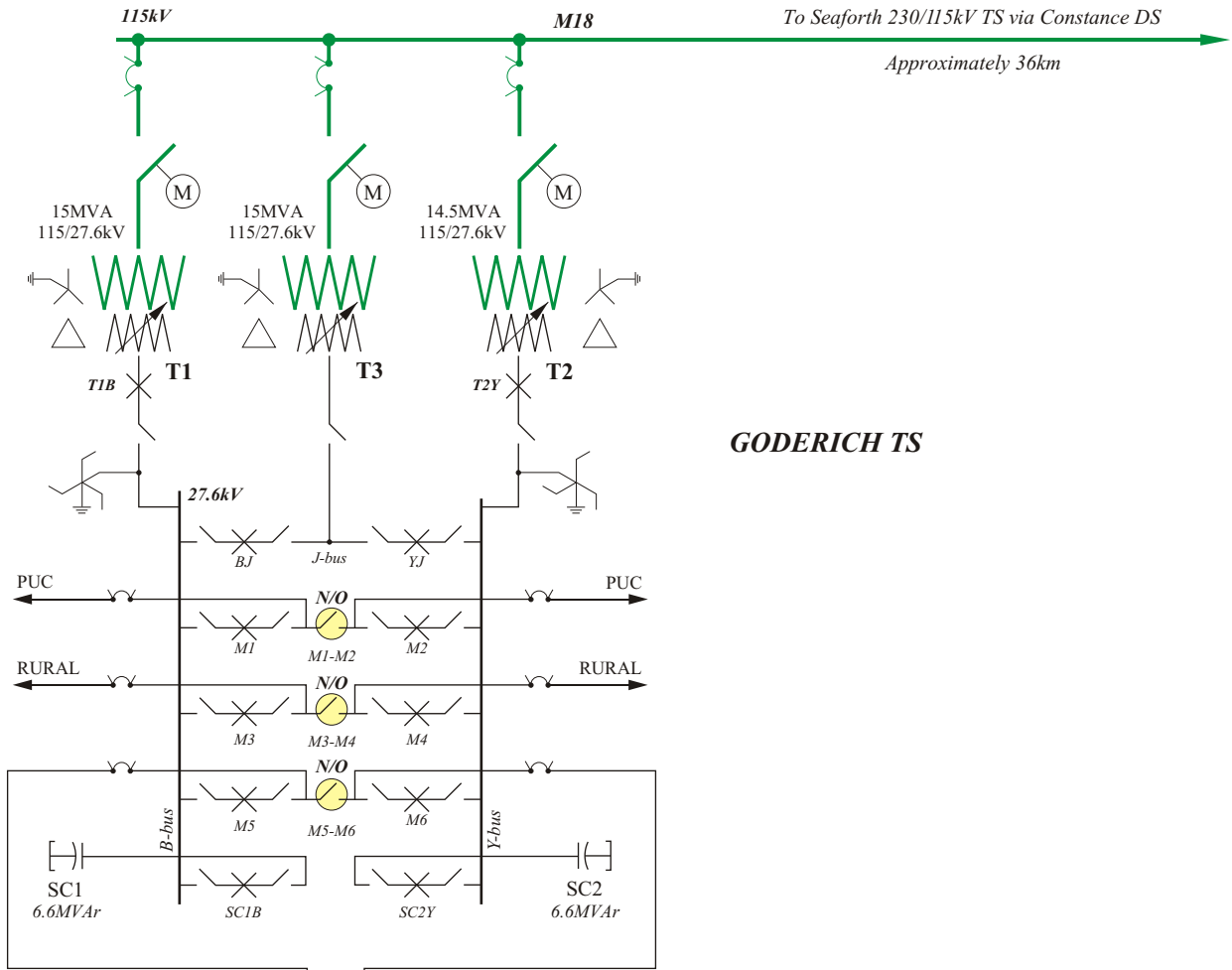
GODERICH TS

**Proposed Incorporation Arrangement
for the Kingsbridge Wind Park**

DIAGRAM 1

14th March 2005

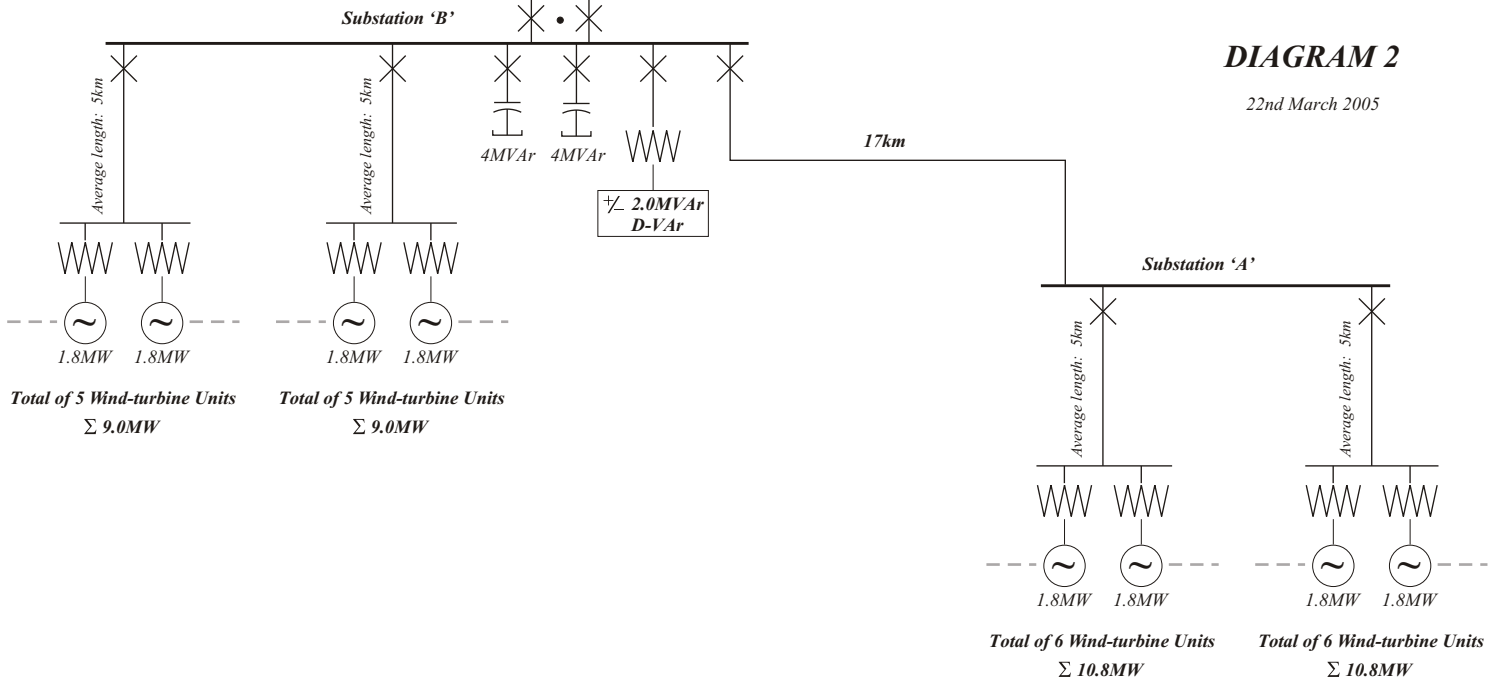




**Alternative Incorporation Arrangement
for the Kingsbridge Wind Park
With a common 27.6kV busbar at Substation B**

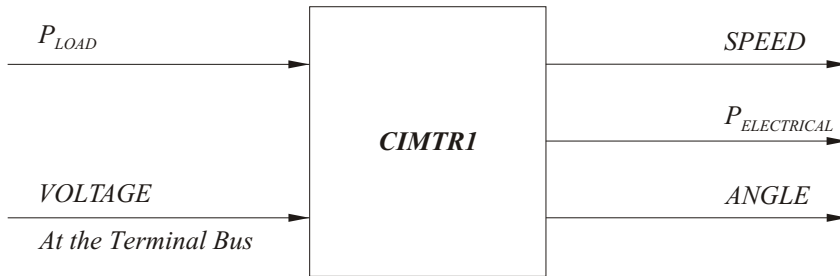
DIAGRAM 2

22nd March 2005



CIMTRI

Induction Generator Model that was used in this Assessment for the Vestas V80 1.8MW WTG

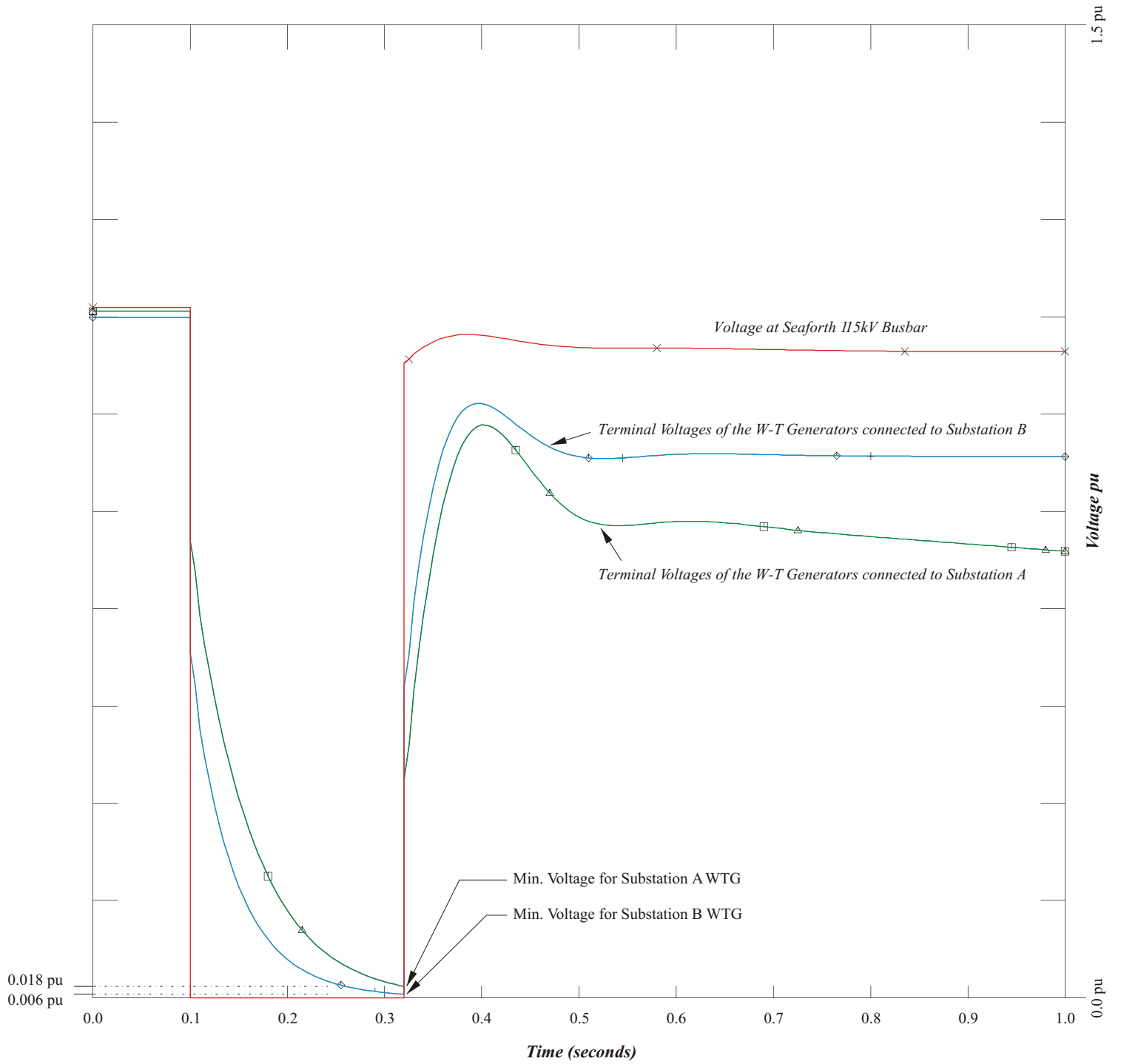


PARAMETER	DESCRIPTION	VALUE
T'	Transient Open-Circuit Time Constant	0.445 sec
T''	Sub-transient Open-Circuit Time Constant	0.00 sec
H	Inertia Constant	3.362 kW-sec/kVA
X	Synchronous Reactance	6.966 pu
X'	Transient Reactance	0.302 pu
X''	Sub-transient Reactance	0.0 pu
X_1	Stator Leakage Reactance	0.126 pu
E_1	Saturation Factors	1.00
$S(E_1)$		1.00 [0.263]
E_2		1.20
$S(E_2)$		1.80 [0.864]
0.	Switch	0.0

Note: The alternative values shown in parenthesis were used in an additional study.

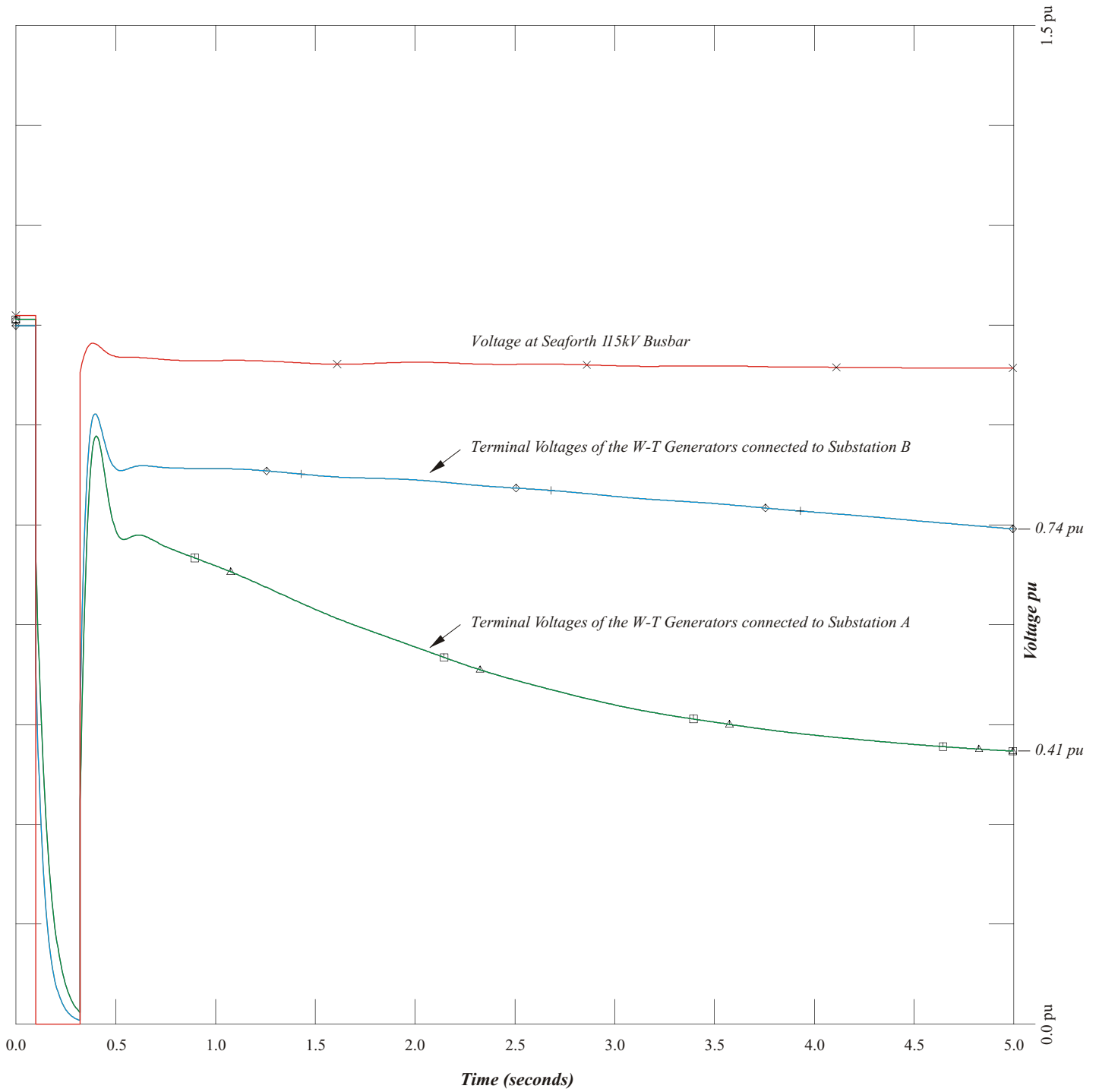
DIAGRAM 3

14th April 2005



Terminal Voltages at the Wind-turbine Generators for a 3-phase Fault on the Seaforth 230/115kV Auto-transformer T5

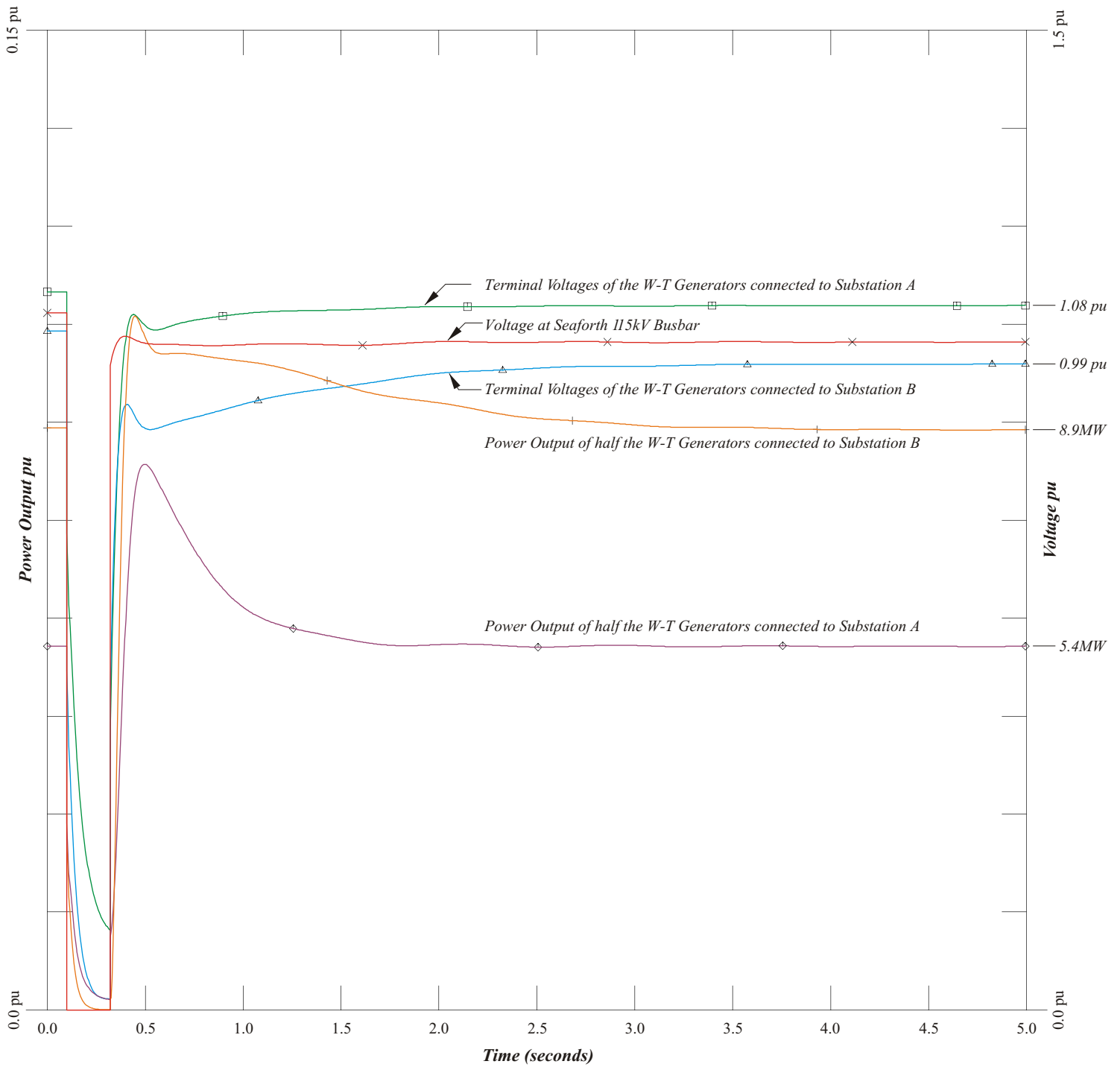
(Without the D-VAR Device In-service)



Terminal Voltages at the Wind-turbine Generators for a 3-phase Fault on the Seaforth 230/115kV Auto-transformer T5

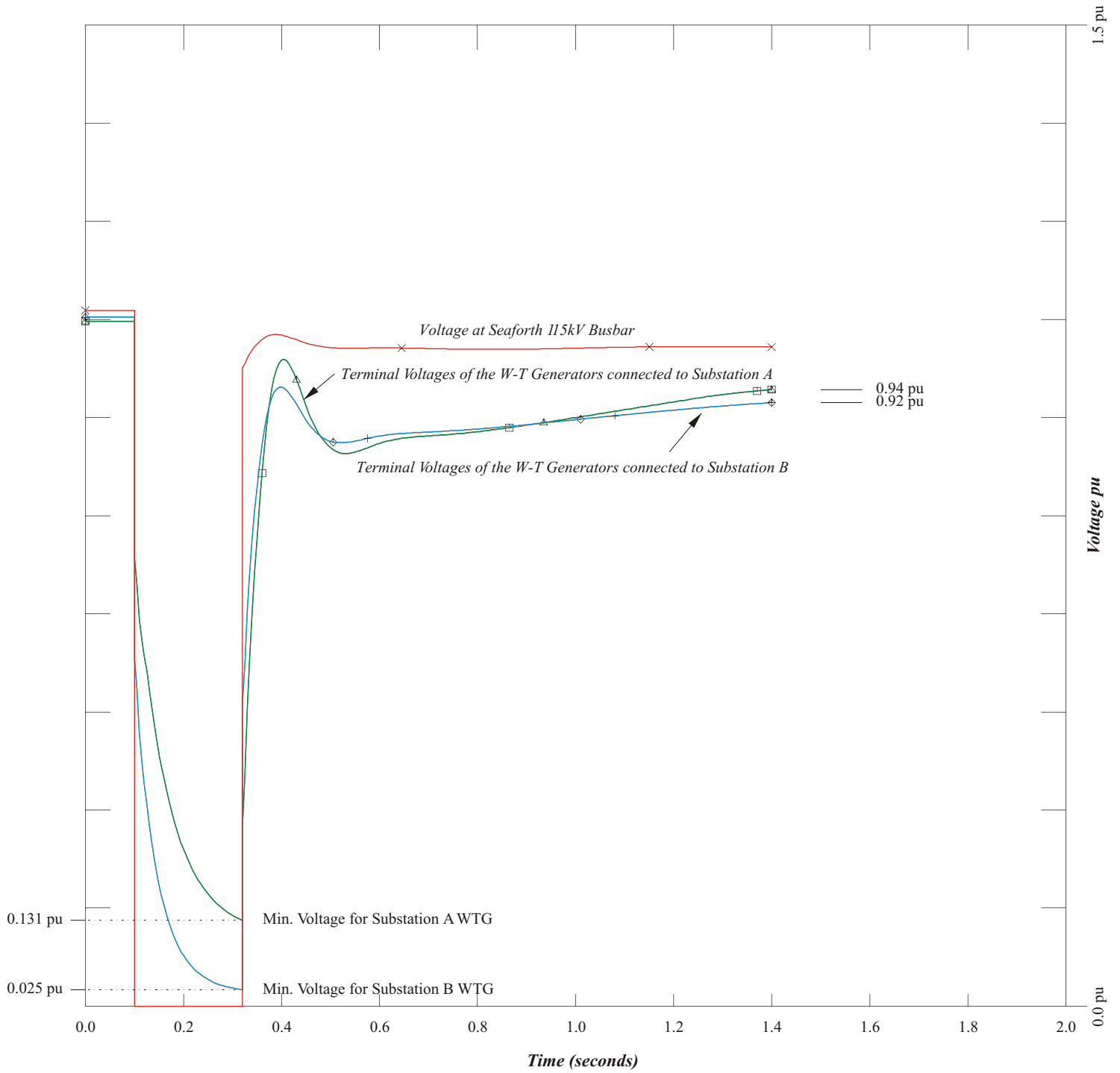
[For a 5-second study period]

(Without the D-VAR Device In-service)



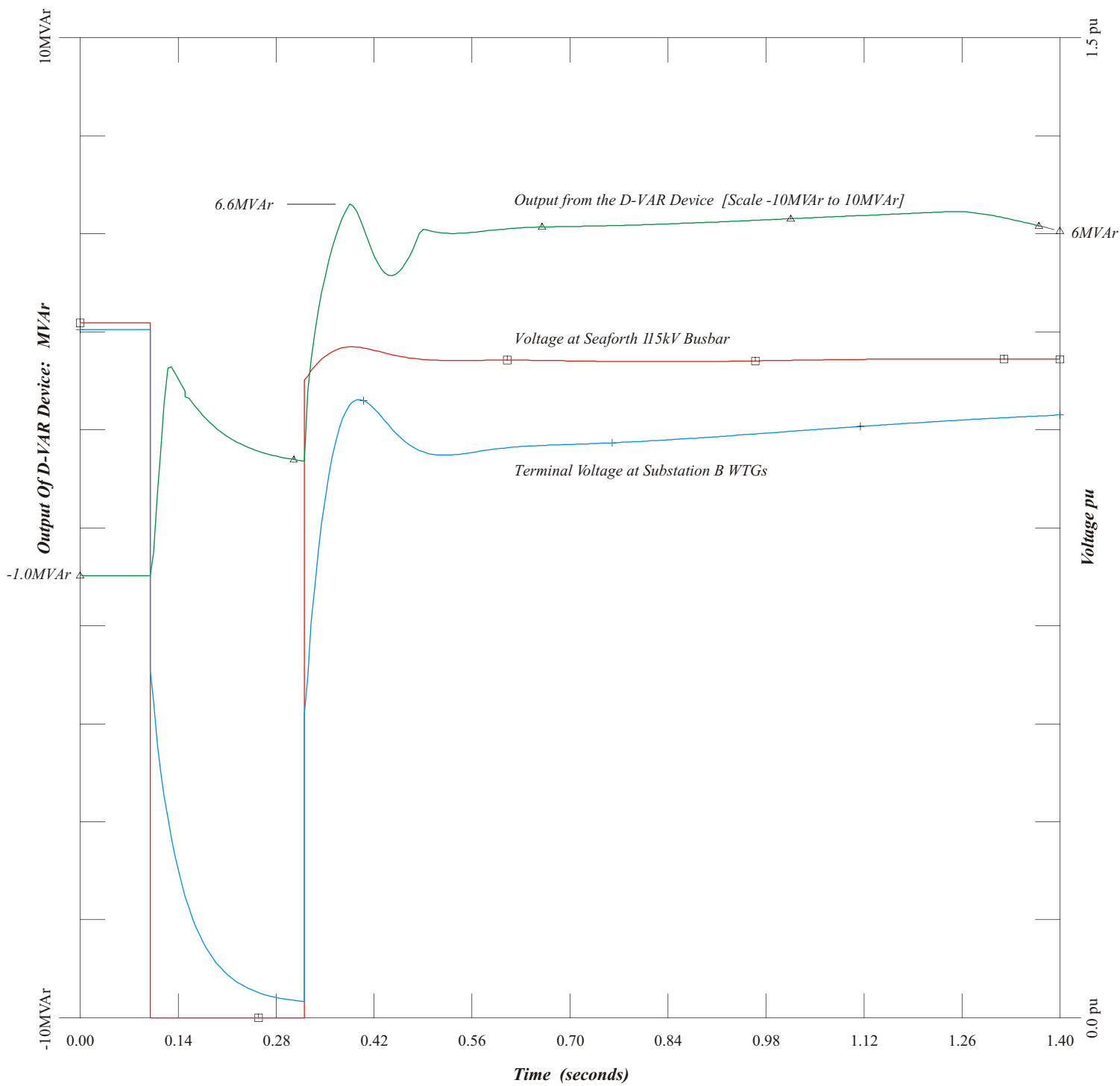
Terminal Voltages at the Wind-turbine Generators for a 3-phase Fault on the Seaforth 230/115kV Auto-transformer T5 & with the output of the W-T Generators connected to Substation A restricted to 50%

(Without the D-VAR Device In-service)



Terminal Voltages at the Wind-turbine Generators for a 3-phase Fault on the Seaforth 230/115kV Auto-transformer T5

(With the D-VAR Device In-service)



Output of the D-VAR Device for a 3-phase Fault on the Seaforth 230/115kV Auto-transformer T5