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Dynamic Stability Assessment of Grain Belt Express Clean Line HVDC Project

Prepared for

Clean Line Energy Partners LLC

Submitted by:

Satish Natti, Ph D
Carlos Grande-Moran, Ph D
Yuri Kazachkov
Nelson J. Bacalao, Ph D

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Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street • P.O. Box 1058
Schenectady, New York 12301-1058 USA
Tel: +1 (518) 395-5000 • Fax: +1 (518) 346-2777
www.siemens.com/power-technologies

Revision History

Date	Rev.	Description
March 2013	1	Initial draft
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Contents

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Executive Summary

Clean Line Energy Partners LLC is currently developing the Grain Belt Express Clean Line (GBX) Project. The project is planned to be a multi-terminal ±600 kV HVDC bi-pole line which will transport large amounts of new, renewable energy, primarily sourced from wind turbine generators (WTG). The wind turbine generation will be independently developed within the Southwest Power Pool's (SPP) geographic footprint in and around the northwestern portion of Oklahoma and in the southwestern portion of Kansas. The power will then be transmitted via the GBX Project approximately 500-550 miles to a location at or near the Palmyra Tap 345kV bus in the Ameren Missouri (AMMO in the MISO) and then a further 200 miles to the Sullivan 765kV substation in the American Electric Power (AEP in the PJM) power systems. The Project will have a planned delivery capability of 3,500 MW as measured at the receiving ends of the HVDC line (500 MW at Palmyra Tap and 3,000 MW at Sullivan). The Sullivan terminal will be designed to receive up to 3,500 MW.

Siemens Industry, Power Technologies International (Siemens PTI) was engaged to evaluate the impacts of the GBX Project from a steady state and dynamic performance point of view. This report presents the stability analysis results to determine the dynamic performance of the study area due to the addition of the GBX Project.

The wind turbine generation is modeled as Type 3 (doubly fed induction generators) and Type 4 (full converter) located within a possible collector system. The collector system design considered in this study is a best engineering estimate based on available wind potential resources in the vicinity of the northwestern portion of Oklahoma and in the southwestern portion of Kansas. It is expected that the wind generation is collected using a 138 kV transmission network connecting the wind parks to main 345 kV stations and then ultimately transferred to the HVDC rectifier station via a 345 kV transmission network. For this analysis, the wind generation was directly connected to the HVDC rectifier station via a 345 kV network without modeling of the 138 kV collection system. Future design studies will include design of the 138 kV system to collect the wind generation and deliver it to the 345 kV transmission network. The collector system losses and reactive power needs of the GBX Project will be covered by the project wind generation and interconnected reactive power sources such that minimal exchange of real and reactive power with SPP at the Point of Interconnection (POI) is maintained under normal operating conditions. However, following the loss of a pole in the GBX project, some of the power flowing through the project will temporarily flow into the SPP system.

As part of the study, several disturbances within the vicinity of the GBX Project were selected to evaluate the dynamic performance of the system. Study methodology and assumptions were discussed with SPP and other affected parties. Affected parties were determined in the January 7, 2013 issued report entitled *Steady State Assessment of the Grain Belt Express Clean Line HVDC Project*.

During the analysis of the Clean Line Plains and Eastern (P&E) project, dynamic reactive support from synchronous condensers was proposed as a solution to handle the low Short Circuit Ratio (SCR[1] of less than 2) at the point of interconnection. Taking advantage of the

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[1] Ratio of 3-phase short circuit MVA without the WTG in place to the total wind turbine generation capacity

P&E project stability study evaluation, and given that the interconnection points for both the P&E and the GBX projects have similar short circuit levels (in the order of 5,000 MVA), dynamic reactive support of 900 MVAr from synchronous condensers was modeled at the rectifier station. The addition of 900 MVAr from synchronous condensers increased the SCR to slightly higher than 2 under system intact conditions. Note that this was modeled as a single synchronous condenser as part of the reactive compensation at the rectifier station and its size and division into smaller units was not optimized in this study as this will be undertaken during the detailed design of the GBX project and its controls.

Three scenarios, 2017 Summer Peak, 2017 Light Load and 2022 Summer Peak, with different dispatch and loading conditions are considered in the study. These scenarios were identified by SPP staff and the affected parties as relevant scenarios considering the project's expected in-service dates.

The following are the main conclusions of the overall system stability analysis:

- As proprietary HVDC models from the yet to be selected HVDC vendor are not available, HVDC models from the PSS/E library are used. These HVDC models do not fully capture the control capability of the HVDC converter stations thus, up to 900 MVAr from a synchronous condenser are required, from a modeling perspective, for the PSS/E stability models to solve by improving the short circuit levels (i.e. system strength) at the Clark County 345 kV substation. This condenser was considered in all cases. Once proprietary HVDC models are provided by the HVDC vendor, the control capability of the HVDC converter can be properly modeled and thus reduce the required amount of synchronous condensers. Furthermore, for reliability and practical reasons, smaller parallel synchronous condensers would be used to make up the required total. This synchronous condenser is to be optimized at the time of the GBX project design

- Faults at Rockport that involve tripping the 765 kV line to Jefferson require the GBX Project generation injection at Sullivan to be reduced, while keeping the full reactive capability of the inverter station available. The associated WTG is assumed to flow in the underlying AC system during the stability runs

- For an N-1-1 outage at Clark County substation, it is necessary to trip approximately 877 MW of the project WTG

The main results of the study that drove these conclusions are summarized below:

- Taking advantage of the P&E Stability Study, and given that the Hitchland and Clark County substations have similar short circuit levels (around 5,000 MVA); up to 900 MVAr from synchronous condensers were proposed for all simulations

- The 2017 Summer Peak case showed stable study area dynamic performance for all selected faults except for 3ph fault at Rockport substation (Fault # 34)
  - For this particular fault, all on-line generating units at the Rockport plant have stepped out of synchronism with the rest of the system. Tripping of these units does not have an adverse impact on the rotor angle stability of rest of the study area

  - By reducing the GBX project injection at Sullivan by 1,500 MW (achieved by blocking one pole), the Rockport generating units remain on-line and in synchronism with the system. Note that full reactive compensation (switched shunts) is required at the converter stations to meet the voltage performance criteria

- The 2017 Light Load case showed stable study area dynamic performance for all selected faults except for Fault # 34. For this fault, the voltages around the Sullivan substation area did not meet the voltage performance criteria

  - By reducing the GBX project injection at Sullivan by 1,500 MW (achieved by blocking one pole), the voltages around the Sullivan substation met the voltage performance criteria

- The 2022 Summer Peak case showed stable study area dynamic performance for all selected faults except for a 3ph fault at Rockport substation (Fault # 34)

  - For this particular fault, all on-line generating units at Rockport plant have stepped out of synchronism with the rest of the system. Tripping of these units does not have adverse impact on the rotor angle stability of the rest of the study area

  - By reducing the GBX project injection at Sullivan 1,500 MW (achieved by blocking one pole), the Rockport generating units remain on-line and in synchronism with the system. Note that full reactive compensation (switched shunts) is required at the converter stations to meet the voltage performance criteria.

Again, it should be noted that it may be possible to reduce the size of the recommended 900 MVAr from synchronous condensers by HVDC control schemes at the converter stations. However, this combination was not tested in this study and it will be part of the reactive optimization of the Project design as well as the selection of the required number of parallel synchronous condensers once proprietary HVDC models become available.