# North-of-the-Delta Offstream Storage Project

# Preliminary Transmission Interconnection Feasibility Analysis

# Final Report

September 7, 2007

USE
Utility System Efficiencies, Inc.

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# 1. Executive Summary

Per a request from CH2MHill/California Department of Water Resources (CDWR)/United States Bureau of Reclamation (USBR), Utility System Efficiencies, Inc (USE) performed a Preliminary Transmission Interconnection Feasibility Analysis (PTIFA) for the North-of-the-Delta Offstream Storage Project (NODOS), "the Project".

The objective of the PTIFA was to identify feasible 230 kV transmission interconnection configurations for 100 MW of generation to transmission facilities in the vicinity of NODOS. The transmission facilities considered are owned by Pacific Gas and Electric (PG&E), Western Area Power Administration (WAPA) and Transmission Agency of Northern California (TANC).

Three (3) Interconnection Configuration Alternatives (ICA) were considered for power flowanalysis and cost estimating:

1. Interconnect to PG&E's proposed Colusa 230 kV Switching Station (CSS) via a 1 mile 230 kV transmission line (ICA 1)
2. Interconnect by looping onto PG&E's 230 kV transmission line from the proposed Colusa Switching Station (CSS) to Vaca-Dixon 230 kV substation, circuit #3 (ICA 2)
3. Interconnect by looping WAPA's Olinda - Obanion 230 kV transmission line (ICA 3)

Power flow analysis showed that all ICAs had acceptable North American Electric Reliability Corporation (NERC)/Western Electricity Coordinating Council (WECC) Category A, B and C performance and the Project did not cause any criteria violations. The results of the power flow analysis did not identify a preferred ICA and instead showed that all ICAs are feasible and do not require any associated transmission network upgrades.

Planning level cost estimates (within ± 25% confidence level) were determined for all ICAs in order to provide a cost comparison and are shown in Table 1.1.

Table 1.1 Interconnection Configuration Alternative Planning Level Cost Estimates

| **Interconnection Configuration Alternative** | **Interconnection Facilities**[1] | **Transmission Network Upgrades**[2] |
|---|---|---|
| 1 - Transmission line to PG&E's Colusa 230 kV Switching Station | | |
| 230 kV Option | $19,524,000 | $0 |
| 115 kV Option | $17,724,000 | $0 |
| 2 - Loop onto PG&E's Colusa - Vaca-Dixon 230 kV transmission line[3] | | |
| 230 kV Option | $20,762,000 | $0 |
| 115 kV Option | $18,961,000 | $0 |
| 3 - Loop onto WAPA's Olinda - Obanion 230 kV transmission line[4] | | |
| 230 kV Option | $20,762,000 | $0 |
| 115 kV Option | $18,961,000 | $0 |

[1] Interconnection Facilities include all facilities and equipment between the generation facility and the point of interconnection, including any modification, additions or upgrades that are necessary to physically and electrically interconnect the generating facility to the transmission system. Interconnection Facilities costs are not reimbursable to the Interconnection Customer.

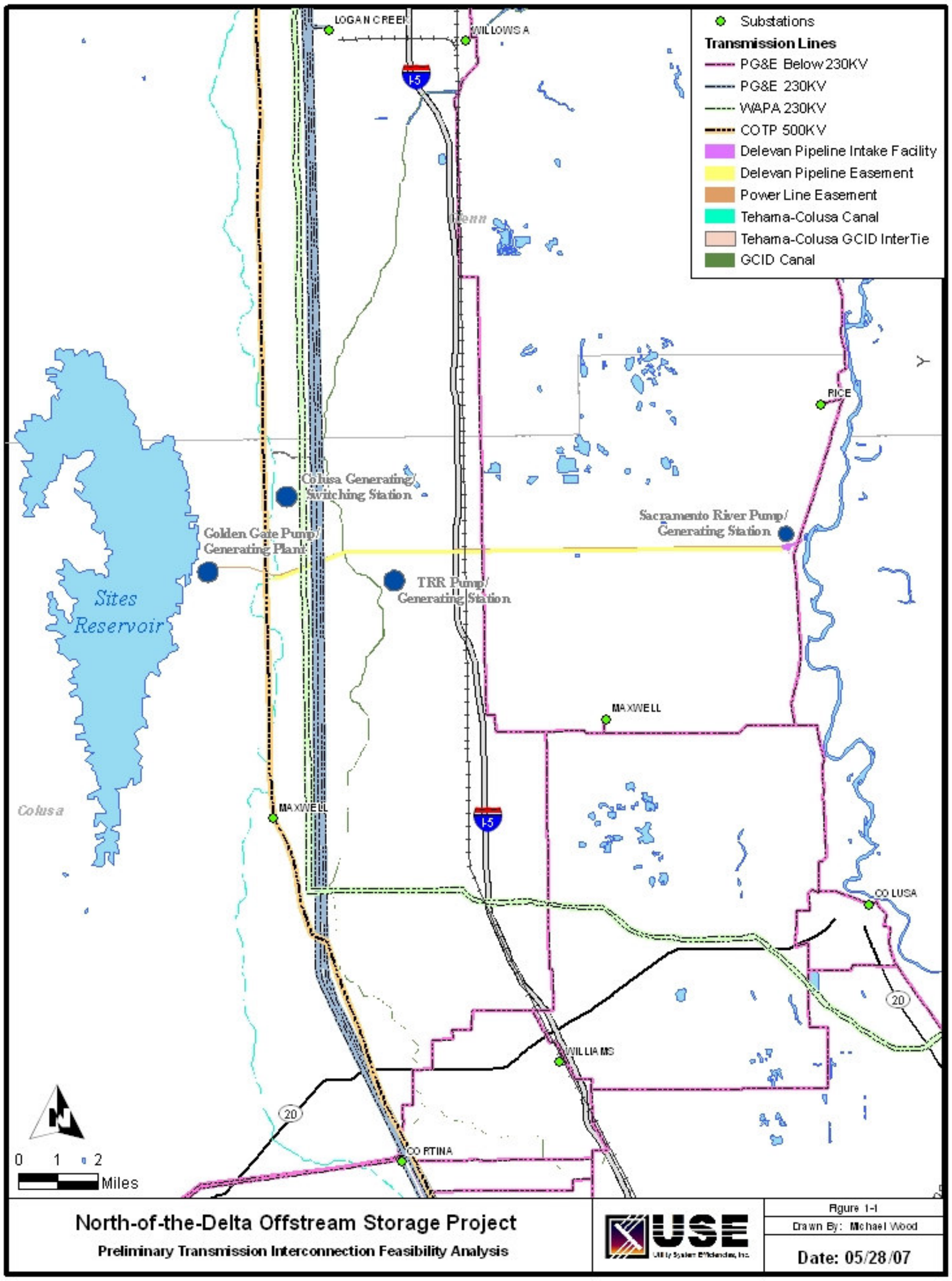
[2] Transmission Network Upgrades are the additions, modifications, and upgrades to the transmission system required at or beyond the point at which the Interconnection Facilities connect to the transmission system to accommodate the interconnection of the generating facility. Network Upgrade costs are reimbursable to the Interconnection Customer.

[3] ICA 2 involves construction of a new substation which may require a land purchase. Cost estimates for land purchases have a ± 50% confidence level.

[4] ICA 3 involves construction of a new substation which may require a land purchase. Cost estimates for land purchases have a ± 50% confidence level.

Figure 1.1 depicts approximate locations of the project facilities and the transmission facilities assessed in this report. It is based on the best information available and should be refined for more detailed engineering.

Figure 1.1: Approximate Locations of Project and Transmission Facilities




Not to Scale

# 2. Study Assumptions

The NODOS Project was assumed to have a maximum generating output of 100 MW from three separate pump/generation locations.

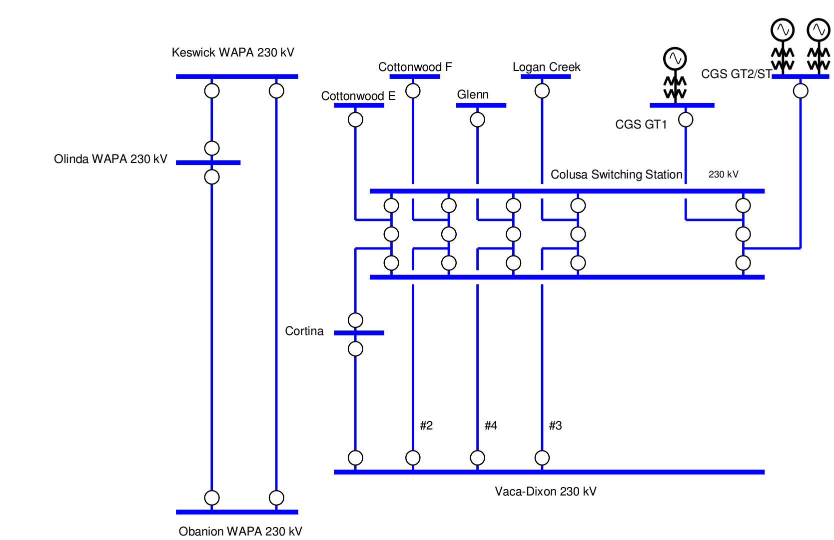
## *2.1. NODOS Area Transmission System*

Based on information provided by CDWR, three preferred interconnection configurations were developed. The Project was assumed to be in the vicinity of the following 230 kV and higher transmission substations and lines:

1. Transmission Substations
   a. PG&E's Cortina 230 kV substation
   b. TANC's Maxwell 500 kV (capacitor station)
   c. PG&E's Logan Creek 230 kV substation
   d. PG&E's proposed Colusa 230 kV Switching Station
2. Transmission Lines
   a. PG&E's proposed Colusa Switching Station - Cortina 230 kV
   b. PG&E's proposed Colusa Switching Station - Vaca-Dixon #2 230 kV
   c. PG&E's proposed Colusa Switching Station - Vaca-Dixon #3 230 kV
   d. PG&E's proposed Colusa Switching Station - Vaca-Dixon #4 230 kV
   e. TANC's Olinda - Maxwell - Tracy 500 kV
   f. WAPA's Keswick - Obanion 230 kV
   g. WAPA's Olinda - Obanion 230 kV

Figure 2.1 shows a single line diagram of the anticipated NODOS area pre-project transmission system configuration.

Figure 2.1: Anticipated NODOS Area Pre-Project Transmission System Configuration




**Anticipated NODOS Area Pre-Project Transmission System Configuration**

## 2.2. Colusa Generating Station

The proposed Colusa 230 kV Switching Station is dependent upon construction of the Colusa Generating Station (CGS). CGS is proposed to be completed by spring 2010. E&L Westcoast LLP (E&LW) signed a power purchase agreement with PG&E in 2006 which will transfer ownership of the power plant to PG&E after commissioning. The configuration of the Colusa 230 kV Switching Station is assumed to be a breaker and a half scheme.

The output of CGS was assumed to be 700 MW as represented in the PG&E 2016 Summer Peak power flow case. According to the CGS California Energy Commission (CEC) Application for Certification (AFC) the total output is 660 MW. The higher output of 700 MW represents a worst case scenario and therefore was used as the CGS nominal output for this study.

## 2.3. Folsom Loop and Sacramento Area Voltage Support Projects

There are two transmission projects that are proposed by SMUD/WAPA to mitigate thermal overloads and voltage violations on the SMUD/WAPA transmission systems. The Folsom Loop project proposes to loop the Lake - Orangevale 230 kV line into Folsom 230 kV substation. The Sacramento Area Voltage Support (SAVS) project proposes to construct a new 230 kV double circuit tower line (DCTL) from Obanion to Elverta. One circuit of this DCTL will connect to Elverta (SMUD). The other circuit will connect directly to the Elverta (SMUD) - Natomas 230 kV line, bypassing Elverta (SMUD), thereby creating an Obanion - Natomas 230 kV line. These transmission projects were assumed to be in service by 2016.

## 2.4. Power Flow Cases

PG&E's 2006 assessment series 2016 summer peak power flow case was used for power flow analysis. The 2016 summer peak case is derived from the Western Electricity Coordinating Council (WECC) 2016 heavy summer "16hs1a1" power flow case. The power flow case represents a 1-in-5 year summer peak load level. PG&E system load was modeled at 29,232 MW with 29,710 MW of generation. The power flow case was modified to reduce flow on Path 66 California Oregon Intertie (COI) to 4,500 MW North to South and to increase Northern California Hydro to 87%.

The generation projects in the California Independent System Operator (CAISO) interconnection queue dated 03-09-2007, that may have an impact on the Project are shown in Table 2.1.

Table 2.1: Generation Projects Having Potential Impacts from CAISO Interconnection Queue

| Queue Position | Type | Output (MW) | Point of Interconnection | Expected On-line Date |
|---|---|---|---|---|
| 2 | Natural Gas | 590 | Contra Costa Power Plant 230 kV | 2009 |
| 12 | Wind | 150 | Birds Landing 230 kV Switching Station | 2006 |
| 22 | Wind | 38 | Birds Landing 230 kV Switching Station | 2007 |
| 24 | Wind | 150 | High Winds 230 kV Substation | 2006 |
| 29 | Wind | 201 | Geysers #17 - Fulton 230 kV Line | 2006 |
| 39 | Wind | 200 | Birds Landing 230 kV Switching Station | 2008 |
| 57 | Natural Gas | 715 | Between Cottonwood and Vaca-Dixon 230 kV | 2010 |
| 74 | Wind | 102 | 230kV line between Pit#3 & Round Mountain | 2008 |
| 81 | Geothermal | 55 | Geysers #17 - Fulton 230 kV Line | 2006 |
| 108 | Wind | 128 | Lambie - Contra Costa 230 kV | 2011 |
| 113 | Wind | 30 | Birds Landing 230 kV Switching Station | 2009 |
| 171 | Wind | 500 | Vaca-Dixon - Tesla 500kV Line | 2011 |

Projects that had completed the Interconnection Feasibility Study (IFS) at the time the power flow cases were created were included in the model. The 500 MW wind project at queue position 171 had not started the IFS process and was not included in the model.

The remaining wind projects in Table 2.1 were modeled as equivalent generators at Geyser 17 230 kV substation, Pit 3 230 kV substation or Birds Landing 230 kV Switching Station. For summer peak conditions the wind projects were modeled at 40% of nameplate capacity. The geothermal and natural gas generators shown in Table 2.1 were already modeled in the power flow case and were dispatched at 100% of nameplate capacity.

The power flow model for each ICA was added to the pre-project case to create the post-project ICA cases. The addition of 100 MW of project generation was accommodated by the PG&E/system swing bus at Morro Bay 230 kV substation.

# 3. Study Methodology

## *3.1. Interconnection Configuration Alternative Development*

Three (3) Interconnection Configuration Alternatives (ICA) were developed for power flow analysis and cost estimating.

1. Interconnect to PG&E’s proposed Colusa 230 kV Switching Station via a 1 mile 230 kV transmission line (ICA 1)
2. Interconnect by looping onto PG&E’s 230 kV transmission line from the proposed Colusa Switching Station (CSS) to Vaca-Dixon 230 kV substation, circuit #3 (ICA 2)
3. Interconnect by looping WAPA's Olinda - Obanion 230 kV transmission line (ICA 3)

Figures 3.1, 3.2 and 3.3 show the conceptual single line diagrams for ICAs 1, 2 and 3 respectively.

Figure 3.1: Interconnection Configuration Alternative 1 Conceptual Single Line Diagram

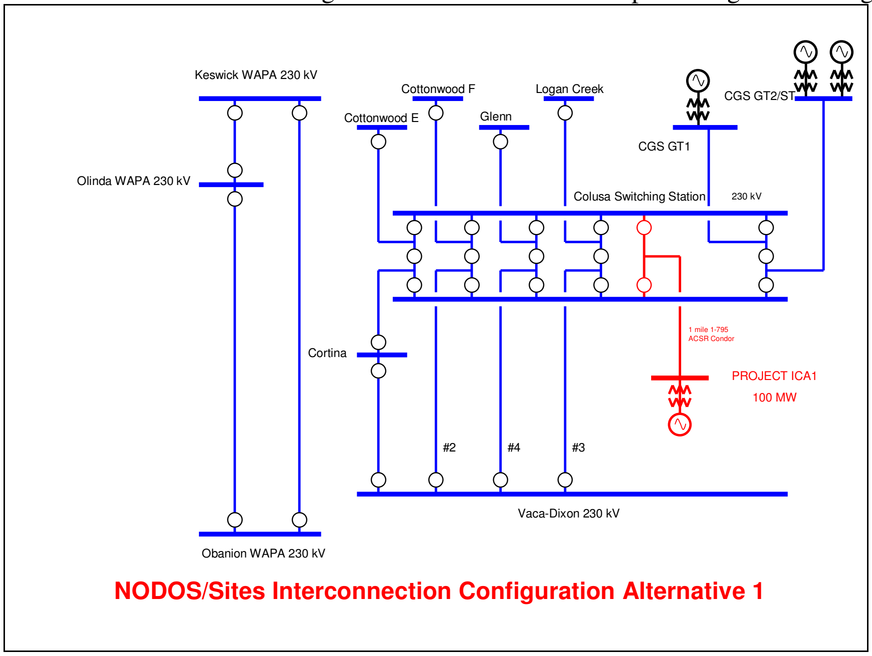



Figure 3.2: Interconnection Configuration Alternative 2 Conceptual Single Line Diagram

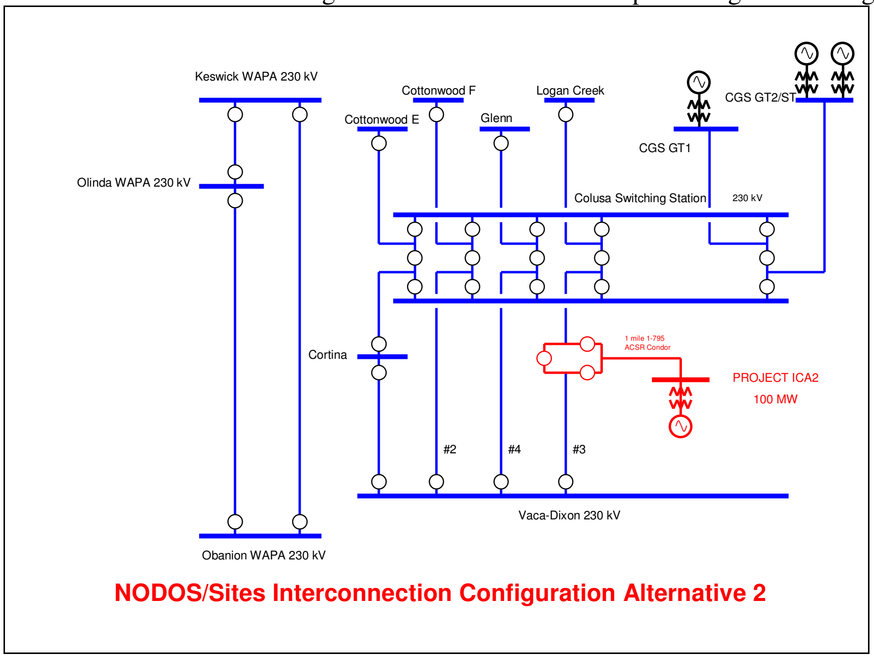
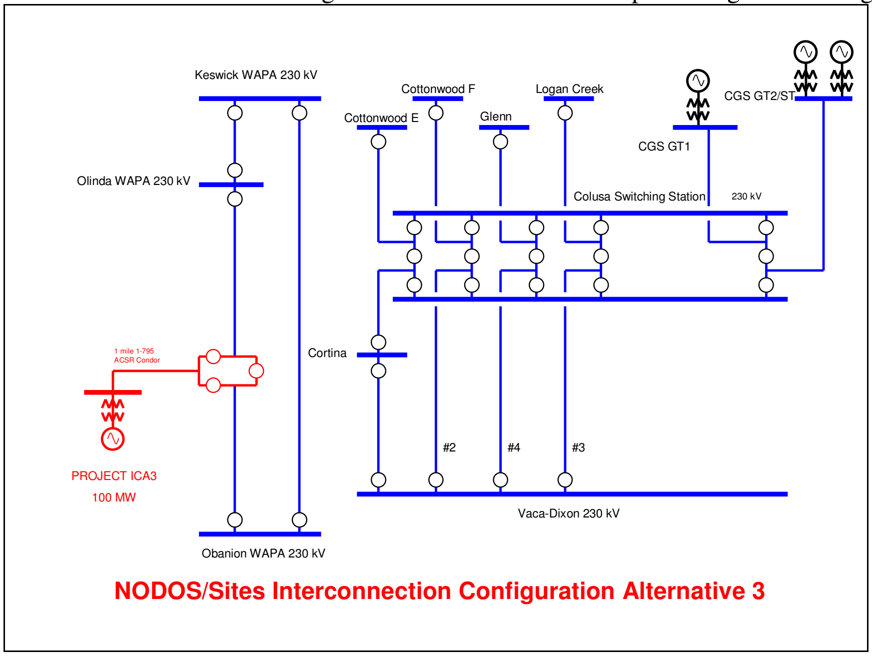


Figure 3.3: Interconnection Configuration Alternative 3 Conceptual Single Line Diagram




The proposed Colusa 230 kV Switching Station is dependent upon construction of the Colusa Generating Station (CGS). CGS is proposed to be completed by spring 2010. E&L Westcoast LLP (E&LW) signed a power purchase agreement with PG&E in 2006 which will transfer ownership of the power plant to PG&E after commissioning. The configuration of the Colusa 230 kV Switching Station is assumed to be a breaker and a half scheme. There is the possibility that additional bays can not be added to the proposed Colusa 230 kV Switching Station. If CGS is cancelled or is not completed by the in-service date of the NODOS Project, ICA 1 is not feasible. ICA 2 would be modified to loop onto PG&E's existing Logan Creek - Vaca-Dixon 230 kV transmission line.

There are two transmission projects that are proposed by SMUD/WAPA to mitigate thermal overloads and voltage violations in the SMUD/WAPA transmission systems. The Folsom Loop project proposes to loop the Lake - Orangevale 230 kV line into Folsom 230 kV substation. The Sacramento Area Voltage Support (SAVS) project proposes to construct a new 230 kV double circuit tower line (DCTL) from Obanion to Elverta. One circuit of this DCTL will connect to Elverta (SMUD). The other circuit will connect directly to the Elverta (SMUD) - Natomas 230 kV line, bypassing Elverta (SMUD), thereby creating an Obanion - Natomas 230 kV line. These transmission projects were assumed to be in service by 2016. If these transmission projects or similar projects are not completed by the in-service date of the NODOS Project then ICA 3 is not a feasible interconnection for generation or pumping scenarios due to inadequate transmission capacity and voltage support on the WAPA transmission system.

## *3.2. Power Flow Analysis*

Power flow analysis considers a snapshot in time where tap changing transformers, switched voltage devices and automatic generation control (area interchange) have had time to adjust. In addition, a swing bus balances the system during each contingency scenario.

Power flow analysis was used to evaluate thermal and voltage performance of the system under NERC/WECC Category A normal (all elements in-service) conditions and NERC/WECC Category B emergency (one element out of service) conditions and selected NERC/WECC Category C emergency (multiple elements out of service) conditions. Complete lists of contingencies studied are included in Appendix A.

Reported normal thermal loading was limited to the condition where a transmission component was loaded above 95% of the appropriate MVA rating (as entered in the power flow database). Reported emergency thermal loading was limited to the condition where a modeled transmission component was loaded over 95% of its appropriate emergency MVA rating (as entered in the power flow database).

Reported normal voltage violations were limited to the conditions where per unit (pu) voltages were less than 0.95 or greater than 1.05. Reported emergency voltage violations were limited to the conditions where, per unit voltages were less than 0.90 or greater than 1.10. In addition, only voltage deviations greater than 5% between the pre and post-contingency and with a 1% increase in voltage deviation between the pre and post-project power flow cases were recorded.

All power flow analysis was conducted with version 16 of General Electric's PSLF/PSDS/SCSC software.

### *3.3. Cost Estimates*

Planning level cost estimates (within ± 25% confidence level) were determined for all feasible ICAs as determined from the power flow analysis, in order to provide a cost comparison. Cost estimates were developed using 2007 dollars from available unit cost estimates.

## 4. Results and Findings

### *4.1. Power Flow Analysis*

Power flow analysis was performed on all pre-project and post-project cases. The results were compared to determine the impacts caused solely by the addition of the Project and to identify the system reinforcements, if any, necessary to mitigate the adverse impacts.

A thermal overload is defined as loading on a facility that exceeds 100% of the appropriate MVA rating (as entered in the power flow database). A thermal overload is caused solely by the Project if the pre-project loading is less than 100% and the post-project loading is greater than 100% of the appropriate MVA rating (as entered in the power flow database).

The power flow analysis showed that all ICAs had acceptable NERC/ WECC Category A Category A, B and C performance and the Project did not cause any criteria violations. The results of the power flow analysis did not identify a preferred ICA and instead showed that all ICAs are feasible and do not have any associated transmission network upgrades.

For ICA 1, the loss of the CSS - Vaca-Dixon #2 and CSS - Vaca-Dixon #4 230 kV transmission lines caused 100% loading on the CSS - Cortina 230 kV transmission line. Since this loading does not exceed 100% it is not a thermal overload, but is an indication of the potential for congestion/overloads in the future. The thermal loading is also dependent upon the output of the NODOS Project and the output of the Colusa Generating Station. If the CGS output is only 660 MW, the likelihood of future congestion or thermal overloads is decreased.

Complete listings of power flow results are included in Appendix B. Selected power flow plots are included in Appendix C.

## 4.2. Cost Estimates

Planning level cost estimates (within ± 25% confidence level) were determined for all feasible ICAs as determined from the power flow analysis, in order to provide a cost comparison and are shown in Tables 4.1 - 4.6. Cost estimates were developed using 2007 dollars from available unit cost estimates. Cost estimates are provided for 230 kV and 115 kV CDWR facilities. Figures 4.1 - 4.3 show single line diagrams of the interconnection facilities for all ICAs.

Table 4.1 Interconnection Configuration Alternative 1 230 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Breaker and a half partial bay (2 circuit breakers)<br>1 mile 1-795 ACSR 230 kV transmission line | $2,984,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 230 kV transmission line<br>Four breaker 230 kV ring bus<br>70 MVA 230/13.8 kV step-up transformer<br>26 MVA 230/13.8 kV step-up transformer<br>16 MVA 230/13.8 kV step-up transformer | $8,750,000<br>$4,264,000<br>$1,343,000<br>$834,000<br>$834,000 |
| Transmission Network Upgrade | none | $0 |
| | ***Total*** | ***$19,524,000*** |

Table 4.2 Interconnection Configuration Alternative 1 115 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Breaker and a half partial bay (2 circuit breakers)<br>1 mile 1-795 ACSR 230 kV transmission line | $2,984,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 115 kV transmission line<br>Four breaker 115 kV ring bus<br>70 MVA 115/13.8 kV step-up transformer<br>26 MVA 115/13.8 kV step-up transformer<br>16 MVA 115/13.8 kV step-up transformer<br>120 MVA 230/115 kV step-up transformer | $6,807,000<br>$3,317,000<br>$1,131,000<br>$601,000<br>$601,000<br>$1,768,000 |
| Transmission Network Upgrade | none | $0 |
| | ***Total*** | ***$17,724,000*** |

Figure 4.1 ICA 1 230 kV and 115 kV Interconnection Facilities Single Line Diagram

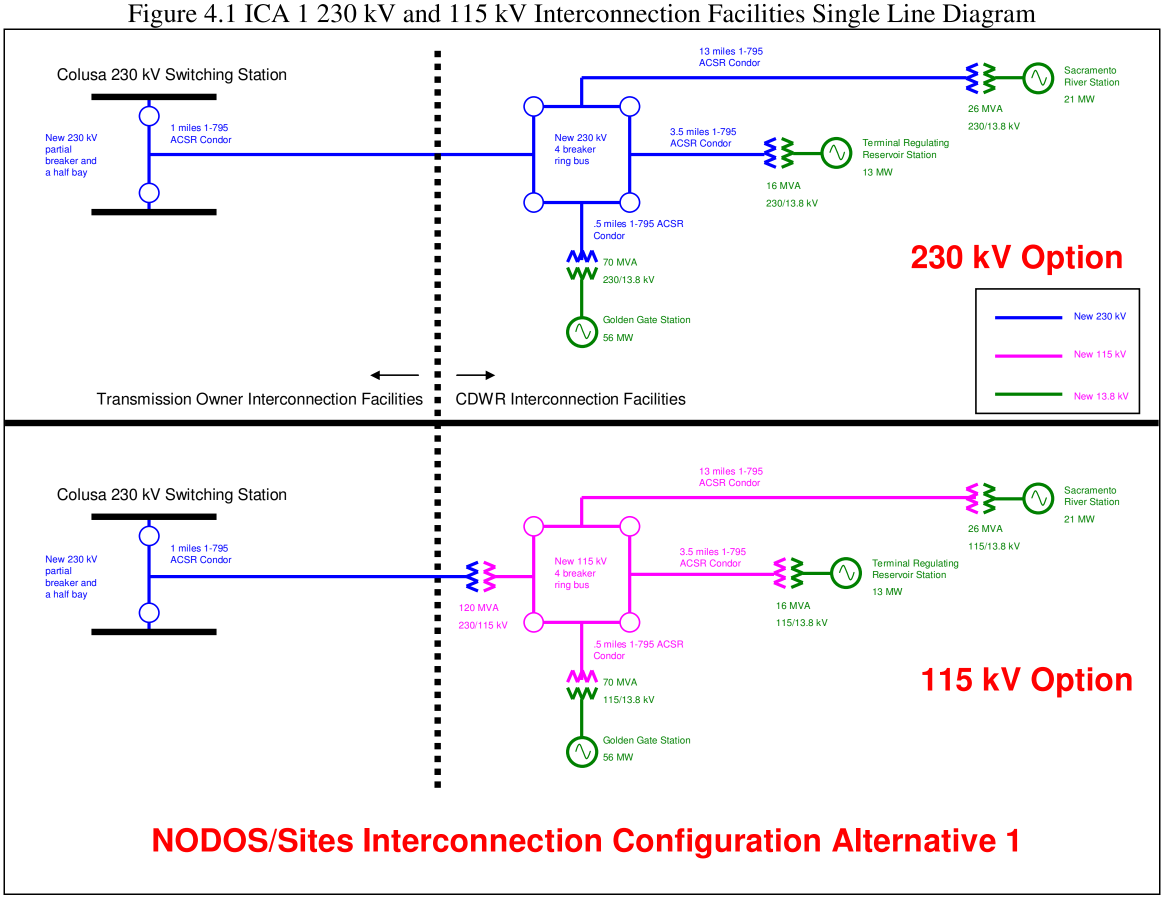


Table 4.3 Interconnection Configuration Alternative 2 230 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Three breaker ring bus<br>Substation development costs<br>1 mile 1-795 ACSR 230 kV transmission line | $3,198,000<br>$1,023,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 230 kV transmission line<br>Four breaker 230 kV ring bus<br>70 MVA 230/13.8 kV step-up transformer<br>26 MVA 230/13.8 kV step-up transformer<br>16 MVA 230/13.8 kV step-up transformer | $8,750,000<br>$4,264,000<br>$1,343,000<br>$834,000<br>$834,000 |
| Transmission Network Upgrade | none | $0 |
| ***Total*** | | ***$20,762,000*** |

Table 4.4 Interconnection Configuration Alternative 2 115 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Three breaker ring bus<br>Substation development costs<br>1 mile 1-795 ACSR 230 kV transmission line | $3,198,000<br>$1,023,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 115 kV transmission line<br>Four breaker 115 kV ring bus<br>70 MVA 115/13.8 kV step-up transformer<br>26 MVA 115/13.8 kV step-up transformer<br>16 MVA 115/13.8 kV step-up transformer<br>120 MVA 230/115 kV step-up transformer | $6,807,000<br>$3,317,000<br>$1,131,000<br>$601,000<br>$601,000<br>$1,768,000 |
| Transmission Network Upgrade | none | $0 |
| ***Total*** | | ***$18,961,000*** |

Figure 4.2 ICA 2 230 kV and 115 kV Interconnection Facilities Single Line Diagram

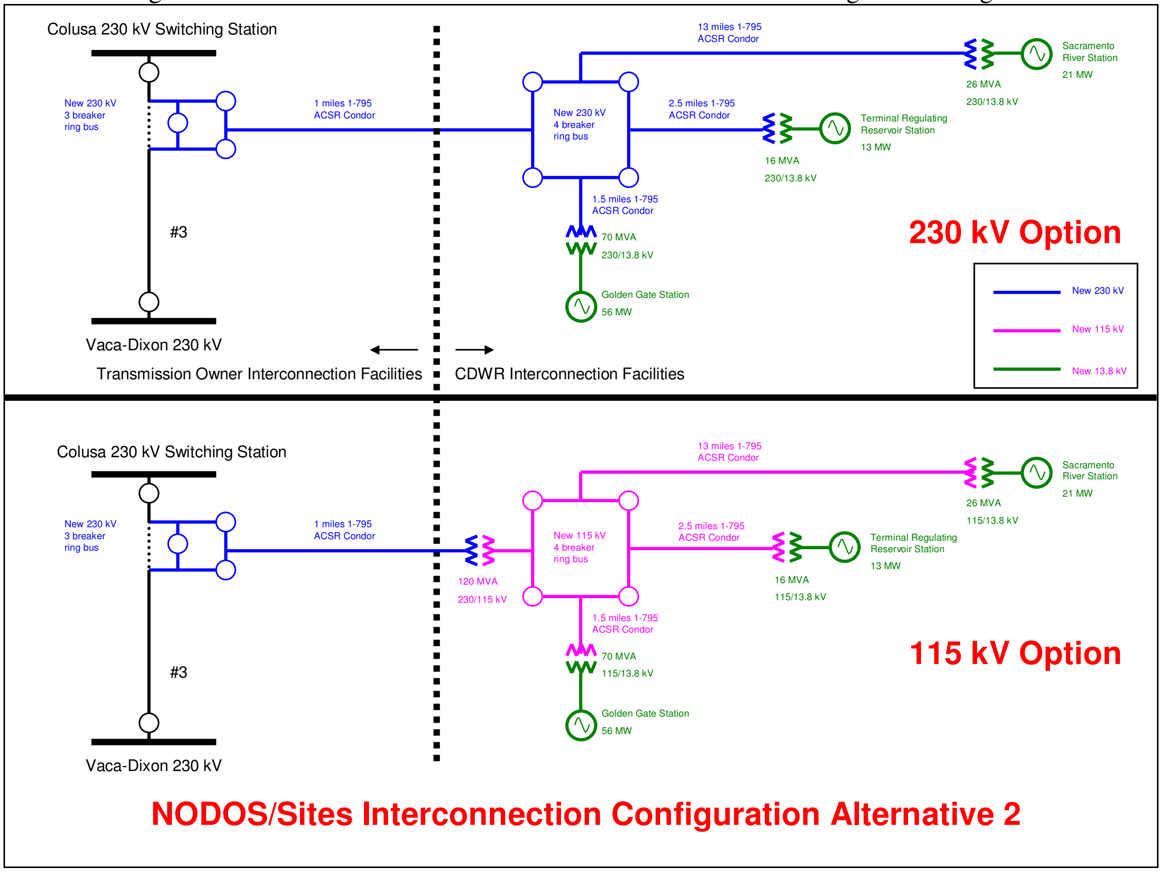


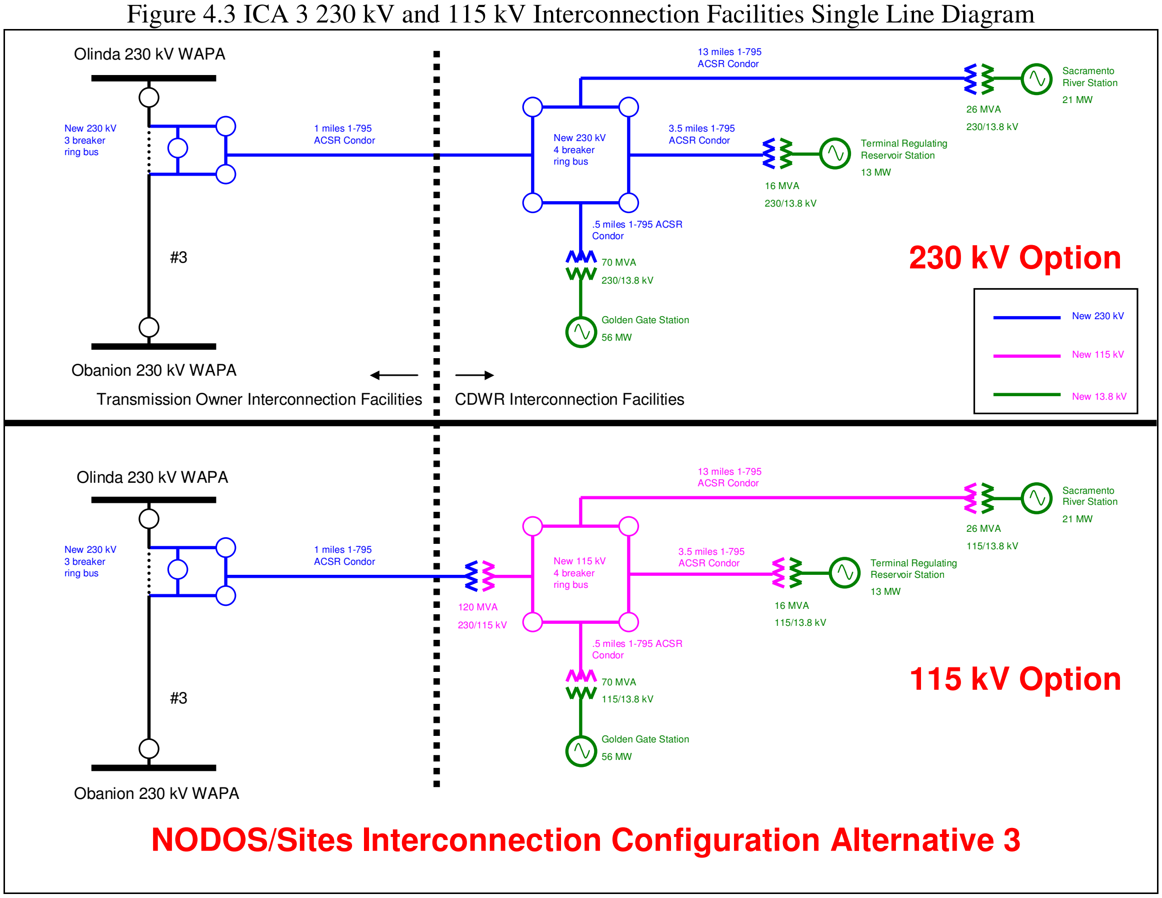
Table 4.5 Interconnection Configuration Alternative 3 230 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Three breaker ring bus<br>Substation development costs<br>1 mile 1-795 ACSR 230 kV transmission line | $3,198,000<br>$1,023,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 230 kV transmission line<br>Four breaker 230 kV ring bus<br>70 MVA 230/13.8 kV step-up transformer<br>26 MVA 230/13.8 kV step-up transformer<br>16 MVA 230/13.8 kV step-up transformer | $8,750,000<br>$4,264,000<br>$1,343,000<br>$834,000<br>$834,000 |
| Transmission Network Upgrade | None | $0 |
| ***Total*** | | ***$20,762,000*** |

Table 4.6 Interconnection Configuration Alternative 3 115 kV Cost Estimate Details

| Type | Description | Estimated Cost |
|---|---|---|
| Interconnection Facilities (PTO) | Three breaker ring bus<br>Substation development costs<br>1 mile 1-795 ACSR 230 kV transmission line | $3,198,000<br>$1,023,000<br>$515,000 |
| Interconnection Facilities (CDWR) | 17 miles 1-795 ACSR 115 kV transmission line<br>Four breaker 115 kV ring bus<br>70 MVA 115/13.8 kV step-up transformer<br>26 MVA 115/13.8 kV step-up transformer<br>16 MVA 115/13.8 kV step-up transformer<br>120 MVA 230/115 kV step-up transformer | $6,807,000<br>$3,317,000<br>$1,131,000<br>$601,000<br>$601,000<br>$1,768,000 |
| Transmission Network Upgrade | none | $0 |
| ***Total*** | | ***$18,961,000*** |

Figure 4.3 ICA 3 230 kV and 115 kV Interconnection Facilities Single Line Diagram



ICA 2 and ICA 3 both involve construction of a new substation which may require land purchases. Cost estimates for land purchases have a ± 50% confidence level.

There are additional costs for the project that includes the electrical components for the pump/generator sets and all associated substation/line work that is part of the overall NODOS Project design. These costs were not estimated as part of this study but are assumed to be nearly equal for all interconnection configuration alternatives.

# 5. Potential Lower Cost Interconnection Configuration Alternatives

There are potential variations of the ICA 1, 2 and 3 that may have lower costs than those shown in Table 4.1, 4.2 and 4.3.

For ICA1, there is the possibility that a partial bay with one element will already exist at the Colusa 230 kV switching station. A center breaker could be added to form a complete bay with two elements. This would only require one circuit breaker and could have lower costs.

For ICA 2 and 3, if the Transmission Provider agrees, instead of looping onto the 230 kV lines with a three breaker ring bus, the project could tap onto the line creating a three terminal line. Disconnect switches would be required at the tap point to allow for sectionalizing and at least one (1) 230 kV circuit breaker would be required at the high side of the Project step-up transformer. This could reduce costs but is subject to the approval of the interconnection Transmission Provider (PG&E or WAPA).

# 6. Recommended Additional Study Work

The study work included as part of this analysis only considered the steady-state power flow performance for generating mode during peak load conditions. Additional steady-state power flow work should be performed for all credible generating and pumping modes and system conditions. Transient stability and post-transient analysis should also be performed all credible generating and pumping modes and system conditions.