

Commonwealth Energy Biogas/PV Mini-Grid Renewable Resources Program

Making Renewables Part of an Affordable and Diverse Electric System in California

Contract No. 500-00-036

Distribution System Characteristics

Project No. 3.1 Dairy Waste to Energy

Task 3.1.10a Final Report

Prepared For:
California Energy Commission
Public Interest Energy Research - Renewables Program

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February 2006

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1

Introduction

1.1 PIER Program Overview

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings' End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

For more information on the PIER Program, please visit the Energy Commission's Web site at: <http://www.energy.ca.gov/research/index.html> or contact the Energy Commission's Publications Unit at 916-654-5200.

For Commonwealth/Commerce Energy Program-specific information, please visit <http://www.pierminigrid.org>.

What follows is a report for the California Energy Commission's Public Interest Energy Research Program, Contract Number 500-00-036, conducted by the Commerce Energy (formerly Commonwealth Energy) Team.

1.1 Commonwealth Program Overview

In June 2001, the Commerce Energy Team was awarded a programmatic contract under the California Energy Commission's Public Interest Energy Research (PIER) Program to conduct research on strategies for making renewable energy more affordable in California. The Commerce Energy approach involves assessing the combined potential of biogas and photovoltaic (PV) resources in a defined study area and identifying how these resources could be developed in a complementary and cost-effective manner. The Commerce Energy Team conducted this research in a real world setting so that the findings could be applied elsewhere in California and thereby benefit more California ratepayers. The local area Commerce Energy selected for its renewable energy research activities is the Chino Basin, referred to in this report as the "study area."

The Chino Basin is rich in PV and biogas resources. Moreover, it is a rapidly growing area with substantial and increasing electrical loads. The underlying goal of the Commerce Energy PIER Renewables Mini-grid Program is to identify potential Building Integrated PV (BIPV) and biogas energy projects, bring innovative technologies and business practices to these projects, assess the benefit to the local electricity distribution system (the "mini-grid"), and then use the findings to develop a business model for siting cost-effective, renewable energy projects. A description of the Commerce Energy PIER Program, including the results of some of the work undertaken to date, is presented in the project Web site, <http://www.pierminigrid.org>.

1.2 Purpose of Detailed Interconnection Study

As part of the Program planning and analysis performed under Project 1.1, information on the local transmission/distribution system was collected in Task 1.1.6, and a power flow study to identify and quantify the benefits of renewable energy projects on the local electric distribution system were performed in Task 1.1.9.

The results of this power flow study were reviewed at the Project 1.1 Critical Project Review (CPR) meeting. The results indicated that there were no "show stoppers" for the expected, high and low biogas and BI-PV generation penetration scenarios studied in this project. In addition, further detailed studies in the following areas were recommended to supplement these power flow study results and ensure successful operation of the mini-grid (and other distribution systems) with significant penetration of distributed generation on the feeders.

A detailed interconnection study in Task 3.1.9 which considers relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication

requirements and short circuit duty impacts with high penetration levels of the distributed biogas and BI-PV generation installed.

A dynamic study of the transient response of high penetration levels of distributed biogas and BI-PV generation to disturbances on nearby feeders or substations in Task 3.1.10 to test the stability of the DG during appropriate transient events.

1.3 Organization of Report

This report presents the results of work conducted in Task 3.1.10a, developing appropriate biogas and BI-PV distributed generation models, and distribution system models for use in the Task 3.1.10b dynamic study. Section 2 presents the goals, objectives and intended results. Section 3 presents the biogas and BI-PV dynamic model. Section 4 presents the distribution and local subtransmission characteristics.

2

Interconnection Requirements and Issues Overview

2.1 Goals and Objectives

The goal of Project 3.1 under Task 3.1.10 is to perform a dynamic study of the transient response of the three high-penetration scenarios of distributed biogas and BI-PV renewable generation scenarios developed for the C9 and D6 distribution circuits to disturbances on adjacent distribution feeders or other nearby substations, to test the stability of the DG during appropriate transient events.

The goal of Task 3.1.10a is to develop dynamic models for BI-PV and biogas distributed generation and distribution characteristics for use in the dynamic study.

The objectives of Task 3.1.10a are to develop appropriate models suitable for use in the GE PSLF/PSDS (positive sequence load flow/positive sequence dynamic simulation) program. This includes the following modeling scenarios:

- Biogas delivering power through synchronous generators.
- BI-PV delivering power through static inverters.
- Distribution and local subtransmission facilities.

2.2 Intended Results

The intended result of Task 3.1.10a is to develop a task report describing the biogas and BI-PV dynamic models, and distribution and local subtransmission facilities, suitable for use with the GE PSLF/PSDS program in the Task 3.1.10b dynamic study, and compatible with CPUC Rule 21 requirements.

3

Biogas and BI-PV Dynamic Models

The objective of Task 3.1.10 is to perform a dynamic study of the transient response of the three BI-PV and biogas renewable generation scenarios developed for the C9 and D6 distribution circuits to disturbances on adjacent distribution feeders or other nearby substations. The purpose of Task 3.1.10a is to develop appropriate biogas and BI-PV models, and distribution system models for use in the Task 3.1.10b dynamic study.

In this task, the models are developed for use in the GE PSLF/PSDS (positive sequence load flow/positive sequence dynamic simulation) program, which is being used for the dynamic study in this project. The BI-PV generation is assumed to deliver power to the utility system through static power inverters, and the biogas generation is assumed to deliver power to the utility system through synchronous generators. The models are also assumed to be compatible with SCE Rule 21 requirements.

3.1 Biogas Synchronous Generators

Currently, two 1.4 MW Waukesha reciprocating engines with synchronous generators are used to generate electricity from digester gas in the IEUA RP#1 wastewater treatment plant, located in the north central portion of the mini-grid, and are represented as part of the D6 distribution circuit. In the high-penetration scenarios studied in this project, the biogas generation capacity is installed in the form of 1.0+MW-scale plants. These MW-scale plants are assumed to consist of one or more 1.4 MW Waukesha engine synchronous generator units.

IEUA engineering staff supplied available generator characteristics for the Waukesha synchronous generators, as shown in Appendix A. The units are 900 rpm, 8-pole, 60 Hz salient-pole synchronous generators. The generators are rated 1.750 MVA, 1.4 MW at 0.80 power factor.

The GE program GENSAL model for representing salient-pole generators was used to represent the 1.7 MVA biogas generators in the dynamic analysis as shown in Table 3.1. The direct (D) and quadrature (Q) synchronous, transient and sub-transient machine data, time constants, and the inertia constant are derived from the Waukesha machine data

supplied in Appendix A. The saturation factors (S1 and S12) and acceleration factor (accel) are representative typical default data for the GENSAL model supplied with GE PSLF Release 13.4.

The GE program EXST1 exciter model used to represent IEEE Type 1 exciters was assumed for this study. This exciter model can be used to represent most modern controlled-rectifier exciter systems adequately whose power source is a power transformer fed from the generator terminals. Representative default data for the EXST1 model supplied with GE PSLF Release 13.4 were used for this study.

No stabilizer model was assumed for these generators. A power system stabilization function is specifically not required for generating plants under 10 MW, as specified in Section D-3a of SCE Rule 21.

Table 3-1: GENSAL Dynamic Model Parameters

EPCL Variable	Data Value	Description
Ld	0.121	D-axis synchronous reactance
Lpd	0.219	D-axis transient reactance
Lppd	0.131	D-axis sub-transient reactance
Lq	0.726	Q-axis synchronous reactance
Lpq	0.0	Q-axis transient reactance
Lppq	0.164	Q-axis sub-transient reactance
L1	0.07	Stator leakage reactance, p.u.
Ra	0.011	Stator resistance, p.u.
Tpdo	2.14	D-axis transient rotor time constant
Tppdo	0.0298	D-axis sub-transient rotor time constant
Tpgo	0.0	Q-axis transient rotor time constant
Tppgo	0.0714	Q-axis sub-transient rotor time constant
S1	0.05	Saturation factor at 1 p.u. flux
S12	0.3	Saturation factor at 1.2 p.u. flux
H	0.827	Inertia constant, sec.
D	0.0	Damping factor, p.u.
rcomp	0.0	Compounding resistance for voltage control, p.u.
xcomp	0.0	Compounding reactance for voltage control, p.u.
accel	0.5	Acceleration factor for network boundary iterations

Table 3-2: EXST1 Dynamic Model Parameters

EPCL Variable	Data Value	Description
Tr	0.0	Filter time constant, sec.
Vimax	0.1	Maximum error, p.u.
Vimin	-0.1	Minimum error, p.u.
Tc	1.0	Lead time constant, sec.
Tb	10.0	Lag time constant, sec.
Ka	200.0	Gain, p.u.
Ta	0.02	Time constant, sec.
Vrmax	5.0	Maximum controller output, p.u.
Vrmin	-5.0	Minimum controller output, p.u.
Kc	0.05	Excitation system regulator factor, p.u.
Kf	0.0	Rate feedback gain
Tf	1.0	Rate feedback time constant, sec.
Tcl	1.0	Lead time constant, sec.
Tbl	1.0	Lag time constant, sec.
Vamax	5.0	Maximum control element output, p.u.
Vamin	-5.0	Minimum control element output, p.u.
Xe	0.04	Excitation transformer effective reactance, p.u.
Ilr	2.8	Maximum field current, p.u.
Klr	5.0	Gain on field current limit

The following voltage trip settings from SCE Rule 21, Section D-2b, Table D.1 shown in Tables 3.3 and frequency trip settings from SCE Rule 21, Section D-2f, Table D.2 shown in Table 3.4 will be assumed for biogas generation in this study.

Table 3-3: Rule 21 Voltage Trip Settings

Voltage range (% voltage)	Max. Trip Time (Seconds/(Cycles))
$V < 50$	0.16 (10)
$50 \leq V < 88$	2 (120)
$110 < V < 120$	1 (60)
$V \geq 120$	0.16 (10)

Table 3-4: Rule 21 Frequency Trip Settings

DG Rating	Frequency range (Hz)	Max. Trip Time (Seconds/(Cycles))
≤ 30 kW	> 60.5	0.16 (10)
	< 59.3	0.16 (10)
> 30 kW	> 60.5	0.16 (10)
	$< \{59.8 - 57.0\}$ (adj setpoint)	Adj 0.16 (10) to 300 (18,000)
	< 57.0	0.16 (10)

Table 3-5: BI-PV Static Inverters

In this study the single unit BI-PV generation AC capacity installed at commercial or industrial sites is assumed to be either 225 kW_{AC} or 450 kW_{AC}. These BI-PV plant sizes are compatible with the BI-PV arrays connecting to the distribution system through one or two 225 kW Xantrex three phase power inverters.

The Xantrex 225 kW inverter voltage and frequency trip settings listed in Table 1-2 of the Xantrex planning manual¹ (see p. 1-4) are shown in Table 3.6. The trip settings listed in the manual for voltage dips less than 50% and for over voltages greater than 137% are significantly shorter than the Rule 21 maximum trip times listed above.

- If the voltage drops below 50% under voltage, trip functions will trip the BI-PV within 6 cycles vs. the 10 cycles required under Rule 21 trip time.
- For voltage dips between 50% and 88%, the under voltage trip functions will trip the BI-PV within 120 cycles, similar to the Rule 21 trip time.
- For over voltages between 110% and 137% the voltage trip function will trip the BI-PV within 120 cycles, vs. the 60 cycles Rule 21 trip time between 110% and 120%, and 10 cycles for over voltages greater than 120%.
- For over voltages greater than 137% the voltage trip function will trip the BI-PV within 2 cycles vs. the 10 cycles Rule 21 trip time.
- The Xantrex frequency trip settings are currently set to trip within 6 cycles vs. the 10 cycle Rule 21 trip time at frequency limit settings for smaller (less than 30 kW) PV systems.

Xantrex should be able to change the trip settings for over voltages, and change trip settings for frequency excursions to be compatible with the SCE Rule 21 requirements for the larger DG units if necessary.

Other important inverter characteristics are that the inverter operates as a current source, operates only at unity power factor, and contains anti-islanding protection as described below:

- The planning manual (p.1-5) states that the inverter is a balanced three-phase current sourcing inverter, and only operates in the presence of a stable utility voltage.

¹ Xantrex International, PV225S 225 kW Grid-Tied Photovoltaic Inverter Planning and Installation Manual, April 2005 Revision A.

- The Xantrex operation and maintenance manual² (p.1-2) states that the inverter maintains unity power factor during operation. The inverter senses utility voltage constantly and constructs the output current waveform to match the utility voltage. The inverter is not capable of varying the off unity power factor.
- The planning manual (p.1-2) states that the inverter contains an integral anti-islanding protection scheme to prevent the inverter feeding power into the distribution circuit in the event of a utility outage.
- The O&M manual (p.1-5) further discusses their anti-island protection procedure to immediately detect, destabilize and shutdown the PV unit in the event of a utility disturbance.

It appears that the objective of the Xantrex voltage and frequency trip settings is to disconnect and remove the PV array as soon as possible after a disturbance is detected on the utility AC system, as the inverter is set to trip significantly faster than required. This fast trip philosophy is probably designed to protect the inverter and PV unit from damage during utility system disturbances, and coordinate with their anti-islanding protection scheme. Hence, the inverter is expected to be compatible with the Rule 21 requirements.

Thus, for this study the BI-PV plants will be modeled as current sources, operating at unity power factor, and with no capability to modulate vars. The short 6 cycle clearing times will be maintained for under voltage dips below 50%. The short 2 cycle clearing times for over voltages will be assumed for over voltages greater than 120%, and the clearing times for over voltages ranging from 110% to 120% will be changed to 60 cycles. The fast 6 cycle trip times for frequency excursions will remain the same as in Table 3.6.

Table 3-6: Xantrex Inverter Voltage and Frequency Trip Settings

Voltage/Frequency Range (%)	Max. Trip Time (Cycles)
$V < 50$	6
$50 \leq V < 88$	120
$110 < V < 137$	120
$V \geq 137$	2
$F > 60.5$	6
$F < 59.3$	6

² Xantrex International, PV225S 225 kW Grid-Tied Photovoltaic Inverter Operation and Maintenance Manual, April 2005 Revision A.

4

Distribution and Local Subtransmission Characteristics

This section describes the C9 and D6 distribution circuits and local 66 kV subtransmission system characteristics used in the GE PSLF/PSDS program for the dynamic study in Task 3.1.10b.

4.1 C9 Distribution Circuit Additions

The C9 12 kV distribution primary circuit described in Section 4 of the Task 3.1.9b report was expanded as described in this section for the dynamic study. Distribution transformers were added at each generation location and the C9 generation was moved to the customer side of the distribution transformer. Table 4.1 shows the new bus numbers and bus names. The renewable generation levels remain the same as for the generation scenarios studied in Task 3.1.9.

The distribution transformers convert the voltage to 480 V for the BI-PV generation locations to be compatible with the BI-PV generation output voltage. The distribution transformers convert the voltage to 12.47 kV for the biogas generation location to be compatible with the biogas generation output voltage. The distribution transformer electrical characteristics for the C9 distribution circuit are presented in Table B.1 of Appendix B.

The C9 12 kV distribution primary circuit electrical characteristics listed in Table B.5 of Appendix B remain the same as presented in the Task 3.1.9b report.

Table 4-1: Circuit C9 Renewable Generation Scenarios

Bus No.	Bus Name	Voltage kV	Scenario A Gen MW	Scenario B Gen MW	Scenario C Gen MW	IC Engine Unit No.
4301	C9A-1	0.480	0.225	0.225	0.225	
4328	C9B-8	0.480	0.225	0.225	0.225	
4329	C9B-9	0.480	0.225	0.225	0.225	
4358	C9C-8	0.480	0.225	0.225	0.225	
4359	C9C-9	0.480	0.225	0.225	0.225	
4360	C9C-10	0.480	0.225	0.225	0.225	
4389	C9D-9	0.480	0.225	0.225	0.450	
4390	C9D-10	0.480	0.225	0.225	0.450	
4314	C9E-4	0.480	0.225	0.225	0.450	
4337	C9F-7	0.480	0.225	0.225	0.450	
4338	C9F-8	0.480	0.225	0.225	0.450	
4339	C9F-9	0.480	0.225	0.225	0.450	
4340	C9F-10	0.480	0.225	0.225	0.450	
4346	C9F-16	0.480	0.225	0.225	0.450	
4349	C9F-19	0.480	0.225	0.225	0.450	
4353	C9C-3	0.480	0.450	0.450	0.450	
4354	C9C-4	0.480	0.450	0.450	0.450	
4356	C9C-6	0.480	0.450	0.450	0.450	
4388	C9D-8	0.480	0.450	0.450	0.450	
4312	C9E-2	0.480	0.450	0.450	0.450	
4313	C9E-3	0.480	0.450	0.450	0.450	
4357	C9-6	12.470		1.400		1
4357	C9-6	12.470		1.400		2
		Totals:	6.075	8.875	8.100	

4.2 D6 Distribution Circuit Additions

The D6 12 kV distribution primary circuit described in Section 5 of the Task 3.1.9b report was expanded in a similar manner as C9 was described in this section for the dynamic study. Distribution transformers were added at each generation location and the D6 generation was moved to the customer side of the distribution transformer. Table 4.2 shows the new bus numbers and bus names. The renewable distributed generation levels remain the same as for the generation scenarios studied in Task 3.1.9.

The distribution transformers convert the voltage to 480 V for the BI-PV generation locations to be compatible with the BI-PV generation output voltage. The distribution transformers convert the voltage to 12.47 kV for the biogas generation location to be

compatible with the biogas generation facilities’ service voltage. The distribution transformer electrical characteristics for the D6 distribution circuit are presented in Table B.2 of Appendix B.

The D6 12 kV distribution primary circuit electrical characteristics listed in Table B.6 of Appendix B remain the same as presented in the Task 3.1.9b report.

Table 4-2: Circuit D6 Renewable Generation Scenarios

		Voltage	Scenario A	Scenario B	Scenario C	IC Engine
Bus No.	Bus Name	kV	Gen MW	Gen MW	Gen MW	Unit No.
4836	D6-4	12.470	1.400	1.400	1.400	1
4836	D6-4	12.470	1.400	1.400	1.400	2
4836	D6-4	12.470	1.400	1.400	1.400	3
4836	D6-4	12.470	1.400	1.400	1.400	4
4836	D6-4	12.470			1.400	5
4807	D6A-7	0.480		0.450		
4863	D6D-3	0.480		0.450		
4846	D6C-6	0.480		0.225		
4823	D6B-3	0.480		0.225		
4803	D6A-3	0.480		0.225		
4822	D6B-2	0.480		0.225		
4844	D6C-4	0.480		0.225		
		Totals:	5.600	7.625	7.000	

4.3 Distribution Substation and 66 kV Configuration

As described in the mini-grid power flow study Task 1.1.6 report, the Chino 66 kV subtransmission system serves 66/12 kV Substation C, as well as 66/12 kV Substations A, B and U. For this dynamic study, Substation C is assumed to be connected to the 230/66 kV Chino Substation 66 kV bus via two 5 mi 66 kV lines, and Substations A, B, and U are assumed to be connected to the 230/66 kV Chino substation 66 kV bus. The 66/12 kV Substation C transformer electrical characteristics are listed in Table B.1 of Appendix B. The 66/12 kV Substation A, B and U transformer electrical characteristics are listed in Table B.3 of Appendix B. The electrical characteristics of the two 66 kV Chino – Substation C subtransmission lines are listed in Table B.4 of Appendix B.

The Mira Loma 66 kV subtransmission system serves 66/12 kV Substation D, as well as 66/12 kV Substations E and F, as described in the mini-grid power flow study Task 1.1.6 report. For this dynamic study, Substation D is assumed to be connected to the 500/230/66 kV Mira Loma Substation 66 kV bus via two 5 mi 66 kV lines, and

Substations E and F are assumed to be connected to the 500/230/66 kV Mira Loma substation 66 kV bus. The 66/12 kV Substation D transformer electrical characteristics are listed in Table B-2 of Appendix B. The 66/12 kV Substation E and F transformer electrical characteristics are listed in Table B.3 of Appendix B. The electrical characteristics of the two 66 kV Mira Loma – Substation D subtransmission lines are listed in Table B.4 of Appendix B.

Appendix A

Waukesha 1750 kVA Engine Generator Machine Data

The following pages contain machine characteristics for the 1750 kVA Waukesha engine generators installed at the IEUA RP#1 treatment facility that use digester gas recovered at the plant to generate electricity and waste heat to displace on-site energy consumption. The engine generator units are 900 rpm, 8-pole, 60 Hz synchronous generators rated 1400 kW @ 0.80 power factor. Machine data includes reactances, time constants and rotor inertia used to develop the dynamics models described in Section 3.



Département ACEO

Projet:

Order 165194 - WAUKESHA

Projet: CHINO BASIN WATER DISTRICT

File francis3442

Date: 17/1/06 Polarité: 8

Alternateur:

A56 S5/8p- 12,47 KV-Pas 2/3- Cat56-8-02

Fréquence (Hz): 60.000

Tension (Volts): 12470

Pas de bobinage: 2/3

Echauffement: B

Vitesse (Tr/Min): 900.000

Cosphi: 0.800

I stator nominal (A): 81.023

kVA nominaux: 1750 : rated kVA

FT n° 4969 A

Empilage global stator= 510

Nombre de spires en série/phase= 288

Pas de bobinage= 8.00 / 12

Empilage rotor= 520

Rendements à Cosphi= 0.800

110%	94.94%	1540.0	1622.0	1
100%	94.86%	1400.0	1475.8	
75%	94.36%	1050.0	1112.7	
50%	92.94%	700.0	753.2	
25%	88.15%	350.0	397.0	

Rotor inertia = 326 KG-M^2

kW electr. kW on shaft

Rendements à Cosphi=1.:

110%	95.96%	1540.0	1604.9
100%	95.80%	1400.0	1461.3
75%	95.12%	1050.0	1103.9
50%	93.51%	700.0	748.6
25%	88.52%	350.0	395.4

Réactances non saturées:

Base: 1750.0 kVA et 12470 Volts

Xd: 121.0%

Xq: 72.6%

X'd: 21.9%

X" d: 13.1%

X" q: 16.4%

X2: 14.8%

X0: 2.4%

Kcc: 0.887

Constantes de temps en sec.:

T'd0: 2.14

T'd: 0.386

T" d: 0.018

T" q: 0.016

Ta: 0.035

Bp0= 15181 C= 27.33 27.3

Nspr= 128 Ra ph-neutre= 0.9915945 ohms à 115°C

Irp0= 41.48 Ra ph-neutre= 0.011159 per unit à 115°C

Irp1= 86.98 R rotor= 1.3938 ohms à 115°C

Icctn= 46.53 Pmec= 12200 Pfer= 29506 U rotor = 121.24

Xs= 0.0703 Cpsup= 1.1600 Dext= 1264.0 Atm= 35990

Kg= 0.829360 1.2068 Da= 974.0 Regards.

Be0= 10722 K2 = 0.866025 E= 6.00 date: 1/17/2006

Xu= 88.8576571 ohms Ldin= 0.1492 Bc= 16227 **F. POURCELOT**

Asdelts= 4,999 / 2287,5 Iréan= 43.79 Bd= 17461 2 événements Iréani= 41.04851644

Asdeltr= 3,158 / 1838,7 1.266

D-Q axis Park model

Project:

Order 165194 - A56 S5/8p - 1750 KVA - 12470 Volts - 60 Hz - 900 Rpm

Salient poles generator

Theoretical unsaturated values

Per unit reference:

kVA= 1750,00 kVA
 U= 12470,00 Volts
 F= 60,00 Hz
 X unity= 1 per unit = 88,85766 Ohms

Resistances and reactances in per unit:

Synchronous:

Ra= 0,01115936	Xad= 1,1401
Xa= 0,0703	Xaq= 0,6559
Xd= 1,2104	
Xq= 0,7262	

Transient:

X'd= 0,2186	Rf= 0,001626
	Xf= 0,170520

Subtransient:

R0= 0,0071	
R1= 0,0129	
R2= 0,0113	
X''d= 0,1312	Rkd= 0,022368
X''q= 0,1640	Xkd= 0,103372
X2= 0,1476	Rkq= 0,028435
X0= 0,024	Xkq= 0,109346

Time constants in seconds at: 115 °C

T'd0= 2,1382 sec	T'd0= 2,1382 sec
T'd= 0,3862 sec	T'd= 0,3862 sec
	T''d0= 0,0298 sec
T''d= 0,0179 sec	T''d= 0,0179 sec
T''q= 0,0161 sec	T''q0= 0,0714 sec
T''d0= 0,0298 sec	T''q= 0,0161 sec
T''q0= 0,0714 sec	Tkd= 0,0123 sec
Ta= 0,0351 sec	Tkq= 0,0102 sec

H (in Seconds) = J (in kGxM²) x 0,002538

D-Q axis Park model

Project:

Order 165194 - A56 S5/8p - 1750 KVA - 12470 Volts - 60 Hz - 900 Rpm

Salient poles generator

Theoretical saturated values

Per unit reference:

kVA= 1750,00 kVA
 U= 12470,00 Volts
 F= 60,00 Hz
 X unity= 1 per unit = 88,85766 Ohms

Resistances and reactances in per unit:

Synchronous:

Ra= 0,01115936	Xad= 1,0584
Xa= 0,0689	Xaq= 0,6075
Xd= 1,1273	
Xq= 0,6764	

Transient:

X'd= 0,1858	Rf= 0,001737
	Xf= 0,131471

Subtransient:

R0= 0,0071	
R1= 0,0129	
R2= 0,0113	
X" d= 0,1115	Rkd= 0,019243
X" q= 0,1394	Xkd= 0,067115
X2= 0,1255	Rkq= 0,027419
X0= 0,023	Xkq= 0,079788

Time constants in seconds at: 115 °C

T'd0= 1,8175 sec	T'd0= 1,8175 sec
T'd= 0,2996 sec	T'd= 0,2996 sec
T" d0= 0,0254 sec	T" d0= 0,0254 sec
T" q0= 0,0665 sec	T" d= 0,0152 sec
T" d= 0,0152 sec	T" q0= 0,0665 sec
T" q= 0,0137 sec	T" q= 0,0137 sec
Ta= 0,0298 sec	Tkd= 0,0093 sec
	Tkq= 0,0077 sec

H (in Seconds) = J (in kGxM²) x 0,002538

Appendix B

Line and Transformer Database

This appendix presents the local 66 kV and 12 kV line data, 66/12 kV substation transformer data, and distribution transformer data for the 12/0.48 kV and 12/12.47 distribution transformers serving the BI-PV systems and biogas engine generation locations for the dynamic study.

Table B-1: C9 Distribution Circuit Transformers

						100 MVA	
From	From	From	To	To	To	Base	Rating
Bus No.	Bus Name	Bus kV	Bus No.	Bus Name	Bus kV	X PU	MVA
1503	66C	66	4000	12C	12	0.082	125
4101	12C9A-1	12	4301	C9A-1	0.48	22	0.25
4212	12C9E-2	12	4312	C9E-2	0.48	11	0.5
4213	12C9E-3	12	4313	C9E-3	0.48	11	0.5
4214	12C9E-4	12	4314	C9E-4	0.48	22	0.25
4128	12C9B-8	12	4328	C9B-8	0.48	22	0.25
4129	12C9B-9	12	4329	C9B-9	0.48	22	0.25
4237	12C9F-7	12	4337	C9F-7	0.48	22	0.25
4238	12C9F-8	12	4338	C9F-8	0.48	22	0.25
4239	12C9F-9	12	4339	C9F-9	0.48	22	0.25
4240	12C9F-10	12	4340	C9F-10	0.48	22	0.25
4246	12C9F-16	12	4346	C9F-16	0.48	22	0.25
4249	12C9F-19	12	4349	C9F-19	0.48	22	0.25
4153	12C9C-3	12	4353	C9C-3	0.48	11	0.5
4154	12C9C-4	12	4354	C9C-4	0.48	11	0.5
4156	12C9C-6	12	4356	C9C-6	0.48	11	0.5
4158	12C9C-8	12	4358	C9C-8	0.48	22	0.25
4159	12C9C-9	12	4359	C9C-9	0.48	22	0.25
4160	12C9C-10	12	4360	C9C-10	0.48	22	0.25
4057	12C9-6	12	4357	C9-6	12.47	1.57	3.5

Table B-2: D6 Distribution Circuit Transformers

						100 MVA	
From	From	From	To	To	To	Base	Rating
Bus No.	Bus Name	Bus kV	Bus No.	Bus Name	Bus kV	X PU	MVA
1513	66D	66	4500	12D	12	0.113	92
4603	12D6A-3	12	4803	D6A-3	0.48	22	0.25
4607	12D6A-7	12	4807	D6A-7	0.48	11	0.5
4622	12D6B-2	12	4822	D6B-2	0.48	22	0.25
4623	12D6B-3	12	4823	D6B-3	0.48	22	0.25
4644	12D6C-4	12	4844	D6C-4	0.48	22	0.25
4646	12D6C-6	12	4846	D6C-6	0.48	22	0.25
4663	12D6D-3	12	4863	D6D-3	0.48	11	0.5
4536	12D6-4	12	4836	D6-4	12.47	0.786	7

Table B-3: Other 66/12 Distribution Transformers

						100 MVA	
From	From	From	To	To	To	Base	Rating
Bus No.	Bus Name	Bus kV	Bus No.	Bus Name	Bus kV	X PU	MVA
24024	CHINO	66	3500	12B	12	0.074	138
24024	CHINO	66	6500	12U	12	0.099	106
24024	CHINO	66	8000	12A	12	0.089	117
24210	MIRALOMA	66	5000	12E	12	0.146	71
24210	MIRALOMA	66	5500	12F	12	0.075	138

Table B-4: 66 kV Sub transmission Line Data

						100 MVA			
From	From	To	To		Base	Base	Base	Rating	Length
Bus No.	Bus Name	Bus No.	Bus Name	CK	R PU	X PU	B PU	MVA	Mi.
24024	CHINO	1503	66C	1	0.02	0.106	0.001	125	5
24024	CHINO	1503	66C	2	0.02	0.106	0.001	125	5
24210	MIRALOMA	1513	66D	1	0.02	0.106	0.001	125	5
24210	MIRALOMA	1513	66D	2	0.02	0.106	0.001	125	5

Table B-5: 12 kV C9 Feeder and Lateral Data

				100 MVA	100 MVA		
From	From	To	To	Base	Base	Rating	Length
Bus No.	Bus Name	Bus No.	Bus Name	R PU	X PU	MVA	Mi.
4000	12C	4052	12C9-1	0.1500	0.2500	12.0	2.0
4052	12C9-1	4053	12C9-2	0.0230	0.0380	12.0	0.3
4053	12C9-2	4054	12C9-3	0.0310	0.0390	11.0	0.3
4054	12C9-3	4055	12C9-4	0.0650	0.0440	7.3	0.3
4054	12C9-3	4056	12C9-5	0.0650	0.0440	7.3	0.3
4056	12C9-5	4057	12C9-6	0.1200	0.1700	12.0	0.3
4052	12C9-1	4101	12C9A-1	0.1107	0.0183	2.9	0.1
4052	12C9-1	4102	12C9A-2	0.1107	0.0183	2.9	0.1
4052	12C9-1	4103	12C9A-3	0.1107	0.0183	2.9	0.1
4053	12C9-2	4121	12C9B-1	0.0714	0.0179	3.7	0.1
4121	12C9B-1	4122	12C9B-2	0.0714	0.0179	3.7	0.1
4121	12C9B-1	4123	12C9B-3	0.0714	0.0179	3.7	0.1
4123	12C9B-3	4124	12C9B-4	0.0714	0.0179	3.7	0.1
4124	12C9B-4	4125	12C9B-5	0.0714	0.0179	3.7	0.1
4125	12C9B-5	4126	12C9B-6	0.1429	0.0179	3.7	0.2
4125	12C9B-5	4127	12C9B-7	0.0714	0.0179	3.7	0.1
4127	12C9B-7	4128	12C9B-8	0.0714	0.0179	3.7	0.1
4128	12C9B-8	4129	12C9B-9	0.0714	0.0179	3.7	0.1
4055	12C9-4	4151	12C9C-1	0.1107	0.0183	2.9	0.1
4055	12C9-4	4152	12C9C-2	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4153	12C9C-3	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4154	12C9C-4	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4155	12C9C-5	0.1107	0.0183	2.9	0.1
4155	12C9C-5	4156	12C9C-6	0.1107	0.0183	2.9	0.1
4155	12C9C-5	4157	12C9C-7	0.1107	0.0183	2.9	0.1
4157	12C9C-7	4158	12C9C-8	0.1107	0.0183	2.9	0.1
4157	12C9C-7	4159	12C9C-9	0.1107	0.0183	2.9	0.1
4159	12C9C-9	4160	12C9C-10	0.1107	0.0183	2.9	0.1
4054	12C9-3	4181	12C9D-1	0.1107	0.0183	2.9	0.1
4181	12C9D-1	4182	12C9D-2	0.1107	0.0183	2.9	0.1
4181	12C9D-1	4183	12C9D-3	0.1107	0.0183	2.9	0.1
4054	12C9-3	4184	12C9D-4	0.1107	0.0183	2.9	0.1
4184	12C9D-4	4185	12C9D-5	0.1107	0.0183	2.9	0.1
4185	12C9D-5	4186	12C9D-6	0.1107	0.0183	2.9	0.1
4185	12C9D-5	4187	12C9D-7	0.1107	0.0183	2.9	0.1
4184	12C9D-4	4188	12C9D-8	0.1107	0.0183	2.9	0.1
4188	12C9D-8	4189	12C9D-9	0.1107	0.0183	2.9	0.1
4189	12C9D-9	4190	12C9D-10	0.1107	0.0183	2.9	0.1
4056	12C9-5	4214	12C9E-4	0.1107	0.0183	2.9	0.1

Table B-5: 12 kV C9 Feeder and Lateral Data (continued)

				100 MVA	100 MVA		
From	From	To	To	Base	Base	Rating	Length
Bus No.	Bus Name	Bus No.	Bus Name	R PU	X PU	MVA	Mi.
4056	12C9-5	4211	12C9E-1	0.0714	0.0179	3.7	0.1
4211	12C9E-1	4212	12C9E-2	0.0714	0.0179	3.7	0.1
4211	12C9E-1	4213	12C9E-3	0.0714	0.0179	3.7	0.1
4057	12C9-6	4231	12C9F-1	0.1107	0.0183	2.9	0.1
4057	12C9-6	4232	12C9F-2	0.1107	0.0183	2.9	0.1
4057	12C9-6	4233	12C9F-3	0.0649	0.0442	7.4	0.3
4233	12C9F-3	4234	12C9F-4	0.0714	0.0179	3.7	0.1
4233	12C9F-3	4235	12C9F-5	0.0714	0.0179	3.7	0.1
4235	12C9F-5	4236	12C9F-6	0.0714	0.0179	3.7	0.1
4233	12C9F-3	4237	12C9F-7	0.0714	0.0179	3.7	0.1
4237	12C9F-7	4238	12C9F-8	0.0714	0.0179	3.7	0.1
4238	12C9F-8	4239	12C9F-9	0.0714	0.0179	3.7	0.1
4239	12C9F-9	4240	12C9F-10	0.0714	0.0179	3.7	0.1
4057	12C9-6	4241	12C9F-11	0.0649	0.0442	7.4	0.3
4241	12C9F-11	4242	12C9F-12	0.0216	0.0147	7.4	0.1
4242	12C9F-12	4243	12C9F-13	0.0216	0.0147	7.4	0.1
4243	12C9F-13	4244	12C9F-14	0.0714	0.0179	3.7	0.1
4243	12C9F-13	4247	12C9F-17	0.0714	0.0179	3.7	0.1
4244	12C9F-14	4245	12C9F-15	0.0714	0.0179	3.7	0.1
4245	12C9F-15	4246	12C9F-16	0.0714	0.0179	3.7	0.1
4247	12C9F-17	4248	12C9F-18	0.0714	0.0179	3.7	0.1
4248	12C9F-18	4249	12C9F-19	0.0714	0.0179	3.7	0.1

Table B-6: 12 kV D6 Feeder and Lateral Data

				100 MVA	100 MVA		
From	From	To	To	Base	Base	Rating	Length
Bus No.	Bus Name	Bus No.	Bus Name	R PU	X PU	MVA	Mi.
4500	12D	4533	12D6-1	0.1400	0.5200	12.0	1.4
4533	12D6-1	4534	12D6-2	0.1000	0.2500	12.0	0.5
4534	12D6-2	4535	12D6-3	0.0420	0.0990	12.0	0.2
4534	12D6-2	4601	12D6-5	0.0433	0.0295	7.3	0.2
4601	12D6-5	4536	12D6-4	0.0433	0.0295	7.3	0.2
4601	12D6-5	4602	12D6A-2	0.0714	0.0179	3.7	0.1
4602	12D6A-2	4603	12D6A-3	0.0714	0.0179	3.7	0.1
4602	12D6A-2	4604	12D6A-4	0.0714	0.0179	3.7	0.1
4604	12D6A-4	4605	12D6A-5	0.0714	0.0179	3.7	0.1
4605	12D6A-5	4606	12D6A-6	0.0714	0.0179	3.7	0.1
4605	12D6A-5	4607	12D6A-7	0.0714	0.0179	3.7	0.1
4601	12D6-5	4621	12D6B-1	0.1430	0.0358	3.7	0.2
4621	12D6B-1	4624	12D6B-4	0.0714	0.0179	3.7	0.1
4621	12D6B-1	4622	12D6B-2	0.0714	0.0179	3.7	0.1
4622	12D6B-2	4623	12D6B-3	0.0714	0.0179	3.7	0.1
4535	12D6-3	4641	12D6C-1	0.1107	0.0183	2.9	0.1
4535	12D6-3	4642	12D6C-2	0.1107	0.0183	2.9	0.1
4642	12D6C-2	4643	12D6C-3	0.1107	0.0183	2.9	0.1
4642	12D6C-2	4644	12D6C-4	0.1107	0.0183	2.9	0.1
4644	12D6C-4	4645	12D6C-5	0.1107	0.0183	2.9	0.1
4645	12D6C-5	4646	12D6C-6	0.1107	0.0183	2.9	0.1
4535	12D6-3	4661	12D6D-1	0.0714	0.0179	3.7	0.1
4661	12D6D-1	4662	12D6D-2	0.0714	0.0179	3.7	0.1
4661	12D6D-1	4663	12D6D-3	0.0714	0.0179	3.7	0.1

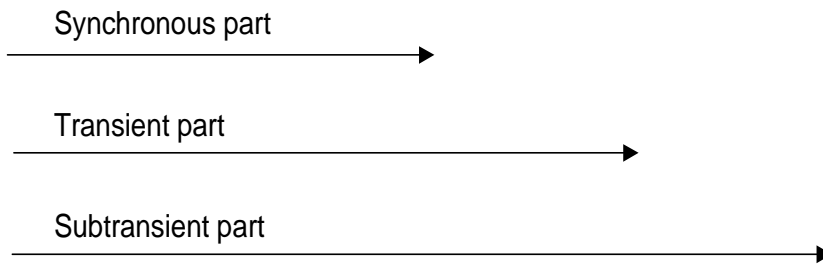
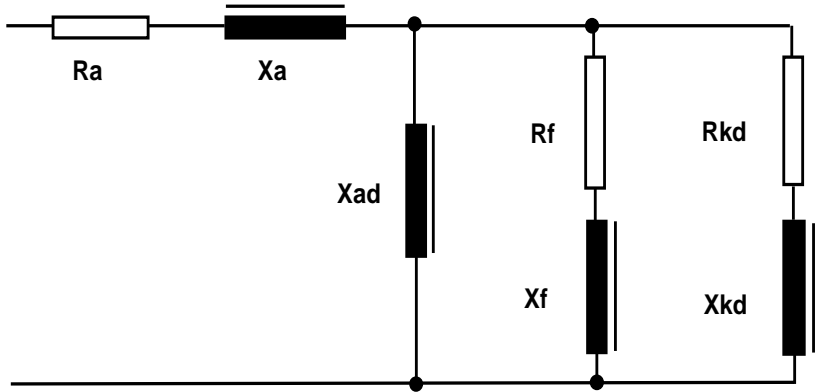
D-Q axis Park model

Project:

Order 165194 - A56 S5/8p - 1750 KVA - 12470 Volts - 60 Hz - 900 Rpm

Salient poles generator

Direct axis - D axis between phase and neutral:



Quadrature axis - Q axis between phase and neutral:

