The Islamic Republic of Pakistan

GENCO Holding Company Limited

Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project in Pakistan

FINAL REPORT (APPENDIX)

October 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Nippon Koei Co., Ltd
Mitsui Consultants Co., Ltd.

4R
JR(先)
16-040

Appendix
of
Final Report
for
The Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project
in Pakistan

Contents

Appendix

2 - 1 EXISTING INSTALLED CAPACITY & CAPABILITY OF X-WAPDA DISCOS SYSTEM AS OF SEPTEMBER, 2013

Existing Installed Capacity & Capability of X-WAPDA DISCOs System As of September, 2013 (Source: NTDC)

Sector	Sr. No.	Name of Power Station	Fuel [6]	Installed Capacity (MW)	Derated Capacity / Capability[1] (MW)		Capability[2] (MW) with Planned Outages		Capability[3] (MW) with Forced Outages		Capability[4] (MW) with gas unavailability	
					Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
		Hydel WAPDA										
Public Sector	1	Tarbela	Water	3478	3633	829	3633	829	3633	829	3633	829
	2	Mangla	Water	1000	960	350	960	350	960	350	960	350
	3	Ghazi Barotha	Water	1450	1357	794	1357	794	1357	794	1357	794
	4	Warsak	Water	243	200	139	200	139	200	139	200	139
	5	Chashma Low Head	Water	184	157	67	157	67	157	67	157	67
	6	Allai Khwar HPP	Water	121	121	60	121	60	121	60	121	60
	7	Jinnah Low Head	Water	96	96	40	96	40	96	40	96	40
	8	Small Hydels[5]	Water	89	64	20	64	20	64	20	64	20
	9	Khan Khwar HPP	Water	72	72	15	72	15	72	15	72	15
		Sub-Total (WAPDA Hydel)		**6733**	**6660**	**2314**	**6660**	**2314**	**6660**	**2314**	**6660**	**2314**
		GENCOs										
	10	TPS Jamshoro #1-4	Gas/FO/RFO	850	700		700	700	700	700	700	700
	11	GTPS Kotri #1-7	Gas/HSD	174	140		140	140	140	140	140	140
		Sub-Total GENCO-I		**1024**	**840**		**840**	**840**	**840**	**840**	**840**	**840**
	12	TPS Guddu Steam #1-4	Gas/FO	640	270		270	270	270	270	270	270
	13	TPS Guddu C.C. #5-13	Gas	1015	885		885	885	885	885	885	885
	14	TPS Quetta	Gas	35	25		25	25	25	25	25	25
		Sub-Total GENCO-II		**1690**	**1180**		**1180**	**1180**	**1180**	**1180**	**1180**	**1180**
	15	TPS Muzaffargarh #1-6	RFO/FO/Gas	1350	1130		1130	1130	1130	1130	1130	1130
	16	NGPS Multan #1&2	Gas/RFO/HSD/FO	195	60		60	60	60	60	60	60
	17	GTPS Faisalabad #1-9	Gas/HSD	244	210		210	210	210	210	210	210
	18	SPS Faisalabad #1&2	FO/Gas/RFO	132	100		100	100	100	100	100	100
	19	Shahdra G.T.	Gas	44	30		30	30	30	30	30	30
		Sub-Total GENCO-III		**1965**	**1530**		**1530**	**1530**	**1530**	**1530**	**1530**	**1530**
	20	FBC Lakhra	Coal	150	30		30	30	30	30	30	30
		Sub-Total GENCO-IV		**150**	**30**		**30**	**30**	**30**	**30**	**30**	**30**
		Sub-Total GENCOs		**4829**	**3580**		**3580**	**3580**	**3580**	**3580**	**3580**	**3580**
		Nuclear										
Private Sector	21	Chashma Nuclear (PAEC)-I	Uranium	325	300		287	271	251	235	251	235
	22	Chashma Nuclear (PAEC)-II	Uranium	340	315		301	285	263	247	263	247
		Sub-Total (Nuclear)		**665**	**615**		**587**	**556**	**514**	**482**	**514**	**482**
		Hydel IPPs										
	23	Jagran Hydel	Water	30	30	10	30	10	30	10	30	10
	24	Malakand-III Hydel	Water	81	81	20	81	20	81	20	81	20
	25	New Bong Escape	Water	84	84	34	84	34	84	34	84	34
		Sub-Total (Hydel IPPs)		**195**	**195**	**64**	**195**	**64**	**195**	**64**	**195**	**64**
		Thermal IPPs										
	26	KAPCO	RFO/Gas/HSD	1638	1386		1324	1253	1240	1170	1240	1170
	27	Hub Power Project (HUBCO)	RFO	1292	1200		1146	1085	1074	1013	1074	1013
	28	Kohinoor Energy Ltd. (KEL)	RFO	131	124		118	112	111	105	111	105
	29	AES Lalpir Ltd.	RFO	362	350		334	316	313	295	313	295
	30	AES Pak Gen (Pvt) Ltd.	RFO	365	350		334	316	313	295	313	295
	31	SEPCOL	RFO	135	119		114	108	107	100	107	100
	32	Habibullah Energy Ltd. (HCPC)	Gas	140	129		123	117	115	109	115	109
	33	Uch Power Project	Gas	586	551		526	498	493	465	493	465
	34	Rousch (Pak) Power Ltd.	Gas	450	395		377	357	354	333	354	333
	35	Fauji Kabirwala (FKPCL)	Gas	157	151		144	137	135	127	135	127
	36	Saba Power Company	RFO	134	125		119	113	112	106	112	106
	37	Japan Power Generation Ltd.	RFO	135	120		115	108	107	101	107	101
	38	Liberty Power Project	Gas	235	211		202	191	189	178	189	178
	39	Altern Energy Ltd. (AEL)	Gas	31	31		30	28	28	26	28	0
	40	Attock Generation PP	RFO	163	156		149	141	140	132	140	132
	41	ATLAS Power	RFO	219	219		209	198	196	185	196	185
	42	Engro P.P. Daharki, Sindh	HSD/Gas/FO	226	217		207	196	194	183	194	183
	43	Saif P.P. Sahiwal, Punjab	Gas/HSD	225	225		215	203	201	190	201	0
	44	Orient P.P. Balloki, Punjab	Gas/HSD	225	225		215	203	201	190	201	0
	45	Nishat P.P. Near Lahore	RFO	200	200		191	181	179	169	179	169
	46	Nishat Chunian Proj. Lahore	RFO	200	200		191	181	179	169	179	169
	47	Foundation Power	Gas	175	175		167	158	157	148	157	148
	48	Saphire Muridke	Gas/HSD	225	209		200	189	187	176	187	0
	49	Liberty Tech	RFO	200	196		187	177	175	165	175	165
	50	Hubco Narowal	RFO	220	214		204	193	192	181	192	181
	51	Halmore Bhikki	HSD/Gas	225	209		200	189	187	176	187	0
		Sub-Total Thermal IPPs		**8294**	**7687**		**7341**	**6949**	**6880**	**6488**	**6880**	**5729**
		Wind Power Projects										
	52	Fauji Wind Power	Wind	50	45	17	45	17	45	17	45	17
	53	Zorlu Energy Wind Power	Wind	56	48	18	48	18	48	18	48	18
		Sub-Total Wind Power Plants		**106**	**93**	**35**	**93**	**35**	**93**	**35**	**93**	**35**
		Total Wind Power Plants		**106**	**93**	**35**	**93**	**35**	**93**	**35**	**93**	**35**
		Total Thermal (Public+Private)		**13788**	**11882**		**11508**	**11085**	**10973**	**10550**	**10973**	**9791**
		Total Hydel (Public+Private)		**6928**	**6855**	**2378**	**6855**	**2378**	**6855**	**2378**	**6855**	**2378**
		Total (X-WAPDA DISCOs System)		**20822**	**18830**	**14295**	**18456**	**13498**	**17921**	**12963**	**17921**	**12204**

1 Hydro Capability is based on last 5 years' average,
2 Planned outages for Summer (June) are taken as 4.5 % and for Winter (December) are taken as 9.6 % for all thermal plants
3 Forced outages for GENCOs plants are taken as 12 % and for IPPs thermal as 6 %.
4 The plants with 9 months gas contracts are not available in winter
5 Small Hydel include; Dargai,Malakand,Rasul,Chichoki Mallian,Shadiwal,Nandi pur,Kurram Garhi,Renala,Chitral
6 Letter from office of GM (WPPO) Letter # GM/WPPO/Dir (Comp)/3240-49 dated 08/04/2013

2 - 2 ANNUAL SUMMARY OF GENERATION ADDITION AS OF SEPTEMBER, 2013

Annual Summary of Generation Addition
As of November, 2013 (Source: NTDC)

Sr. #	Fiscal Year	Name of Project	Agency	Fuel	Installed Capacity (MW)	Comissioning Date	Addition/year (MW)	Total Installed Capacity (MW)
		Existing capacity						20839
	2013-14						475	21314
1		Duber Khwar HPP	WAPDA	Hydel	130	Dec. 2013		
2		Rehabilitation of GENCOS	GENCO	Gas	245	Dec. 2013		
3		Quaid-e-Azam Solar Park Phase-1	PPDB	Solar	100	Jun. 2014		
	2014-15						2356	23670
4		UCH-II	PPIB	Gas	404	Jan. 2014		
5		Guddu(747) Phase-1	GENCO	Gas	243	Apr. 2014		
6		Guddu(747) Phase-2	GENCO	Gas	243	May. 2014		
7		Guddu(747) Phase-3	GENCO	Gas	261	Sep. 2014		
8		Quaid-e-Azam Solar Park Phase-2	PPDB	Solar	300	Sep. 2014		
9		Foundation Wind Energy-2	AEDB	Wind	50	Oct. 2014		
10		Foundation Wind Energy-1	AEDB	Wind	50	Jan. 2015		
11		Three Gorges Wind Farm	AEDB	Wind	50	Jan. 2015		
12		Nandipur Power project	GENCO	Oil	425	Mar. 2015		
13		Sapphire wind	AEDB	Wind	50	Mar. 2015		
14		Yunus Energy	AEDB	Wind	50	Apr. 2015		
15		United Energy	AEDB	Wind	100	Apr. 2015		
16		Metro power	AEDB	Wind	50	May. 2015		
17		Tapal Wind Energy Pvt. Ltd.	AEDB	Wind	30	May. 2015		
18		Sachal Energy	AEDB	Wind	50	Jun. 2015		
	2015-16						1250	24920
19		Quaid-e-Azam Solar Park Phase-3	PPDB	Solar	600	Sep. 2015		
20		JHM-WPP#1	AEDB	Wind	50	Feb. 2016		
21		JHM-WPP#2	AEDB	Wind	50	Mar. 2016		
22		JHM-WPP#3	AEDB	Wind	50	Apr. 2016		
23		JHM-WPP#4	AEDB	Wind	500	Apr. 2016		

Annual Summary of Generation Addition
As of November, 2013 (Source: NTDC)

Sr. #	Fiscal Year	Name of Project	Agency	Fuel	Installed Capacity (MW)	Comissioning Date	Addition/year (MW)	Total Installed Capacity (MW)
	2016-17						3572	28492
24		JHM-WPP#5	AEDB	Wind	50	Aug. 2016		
25		JHM-WPP#6	AEDB	Wind	50	Aug. 2016		
26		JHM-WPP#7	AEDB	Wind	50	Sep. 2016		
27		JHM-WPP#8	AEDB	Wind	50	Sep. 2016		
28		JHM-WPP#9	AEDB	Wind	50	Sep. 2016		
29		JHM-WPP#10	AEDB	Wind	50	Oct. 2016		
30		JHM-WPP#11	AEDB	Wind	50	Oct. 2016		
31		JHM-WPP#12	AEDB	Wind	50	Oct. 2016		
32		JHM-WPP#13	AEDB	Wind	50	Nov. 2016		
33		JHM-WPP#14	AEDB	Wind	35	Nov. 2016		
34		JHM-WPP#15	AEDB	Wind	35	Nov. 2016		
35		Neelum Jhelum Hydel	WAPDA	Hydel	969	Nov. 2016		
36		Golen Gol HPP	WAPDA	Hydel	106	Dec. 2016		
37		Patrind HPP	PPIB	Hydel	147	Dec. 2016		
38		CHASNUPP (C3)	PAEC	Nuclear	340	Dec. 2016		
39		Phandar Hydro	WAPDA	Hydel	80	May. 2017		
40		Tarbela 4th ext.Hydro	WAPDA	Hydel	1410	Jun. 2017		
	2017-18						10082	38574
41		Engro Thar Coal (Phase-1)	PPIB	Coal	600	Aug. 2017		
42		Keyal Khwar	WAPDA	Hydel	122	Oct. 2017		
43		CHASHNUPP (C4)	PAEC	Nuclear	340	Oct. 2017		
44		Pakistan Power Park Phase-1 (Gaddani)	PPIB	Coal	1320	Dec. 2017		
45		Gulpurpoonch river	PPIB	Hydel	100	Dec. 2017		
46		Import of power from CASA	GoP	Import	1000	May. 2018		
47		Pakistan Power Park Phase-2 (Gaddani)	PPIB	Coal	5280	Jun. 2018		
48		Bin Qasim PP	PPIB	Coal	1320	Jun. 2018		

Annual Summary of Generation Addition
As of November, 2013 (Source: NTDC)

Sr. #	Fiscal Year	Name of Project	Agency	Fuel	Installed Capacity (MW)	Comissioning Date	Addition/year (MW)	Total Installed Capacity (MW)
	2018-19						4090	42664
49		Engro Thar Coal (Phase-2)	PPIB	Coal	600	Aug. 2018		
50		TPS Jamshoro(Unit Add.) Phase-1	GENCO	Coal	600	Nov. 2018		
51		Sehra HPP	PPIB	Hydel	130	Dec. 2018		
52		TPS Jamshoro(Unit Add.) Phase-2	GENCO	Coal	600	Mar. 2018		
53		Dasu Phase-1	WAPDA	Hydel	2160	Jun. 2019		
	2019-20						4471	47135
54		Lower Pallas Valley□	WAPDA	Hydel	665	Dec. 2019		
55		Coastal Karachi (K2)	PAEC	Nuclear	1110	Apr. 2020		
56		Lower Spat Gah	WAPDA	Hydel	496	May. 2020		
57		Karot HPP	PPIB	Hydel	720	Jun. 2020		
58		Azad Pattan HPP	PPIB	Hydel	640	Jun. 2020		
59		Suki Kinari HPP	PPIB	Hydel	840	Jun. 2020		

References:
i. As per data provided by WAPDA Hydel, GENCO, PPIB and PAEC information
ii. COD Schedule (Anticipated) by AEDB for Wind Power Projects in Sindh Province and are subjected to change

Notes:
i. Tarbela 5th Extension has not been included because of no ground realities
ii. PPIB's plants i.e Star Thermal & Grange Holding have not been included due to no physical progress at site
iii. Harpo, Basho, Trappi and PHYDO phants have also not been included due to non-connectivity with National Grid.
iv. Lower Spat Gah and Lower Palas Valley projects are linked with schedule of Dasu due to power evacuation issues.
v. Gabral Kalam, Kalam Asrit, Asrit Kedam and Madyan are linked with Basha Dam project due to power evacuation issues.

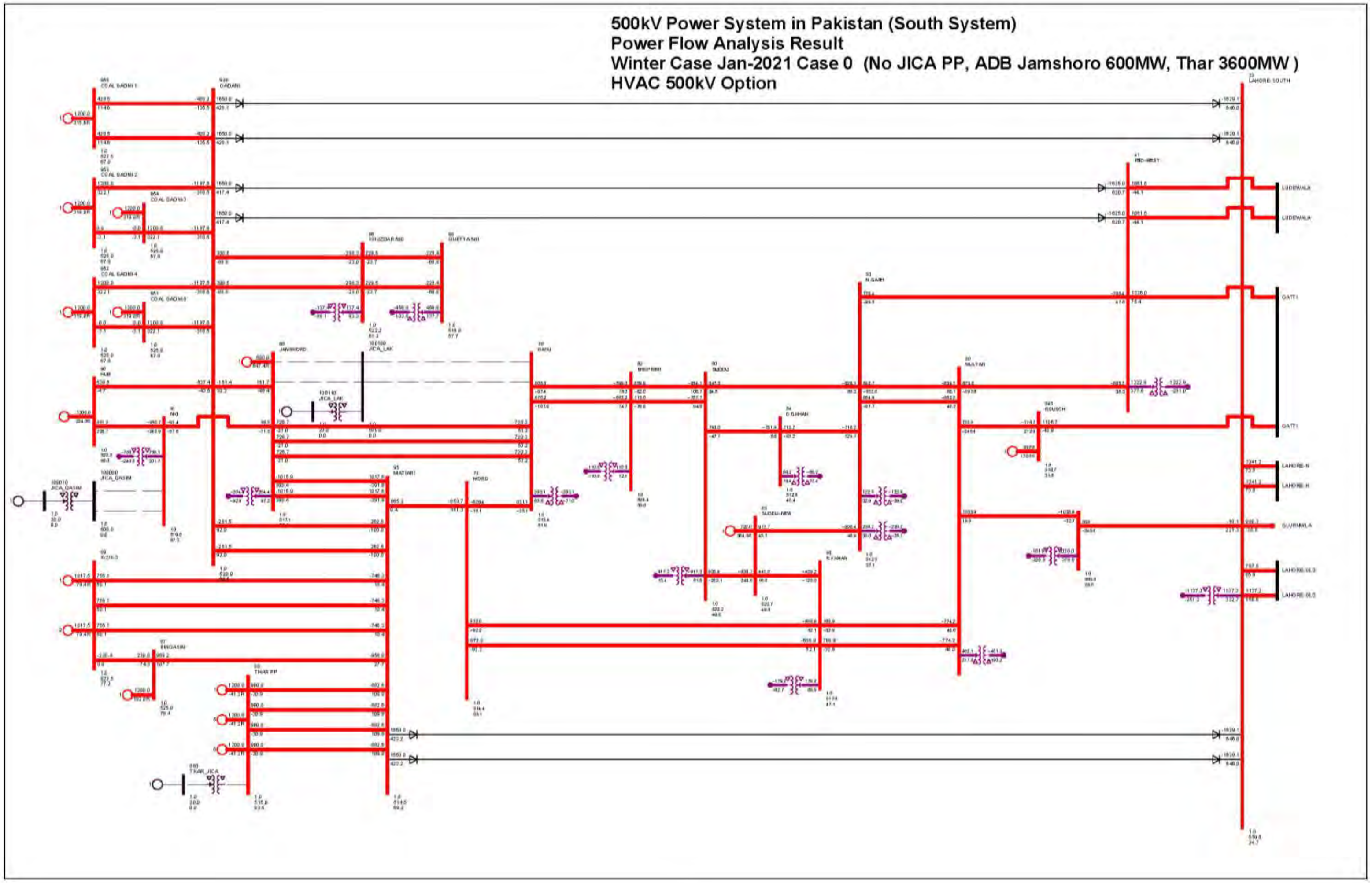
2 - 3 PEAK DEMAND FORECAST

Peak Demand Forecast Summary
(Source: NTDC)

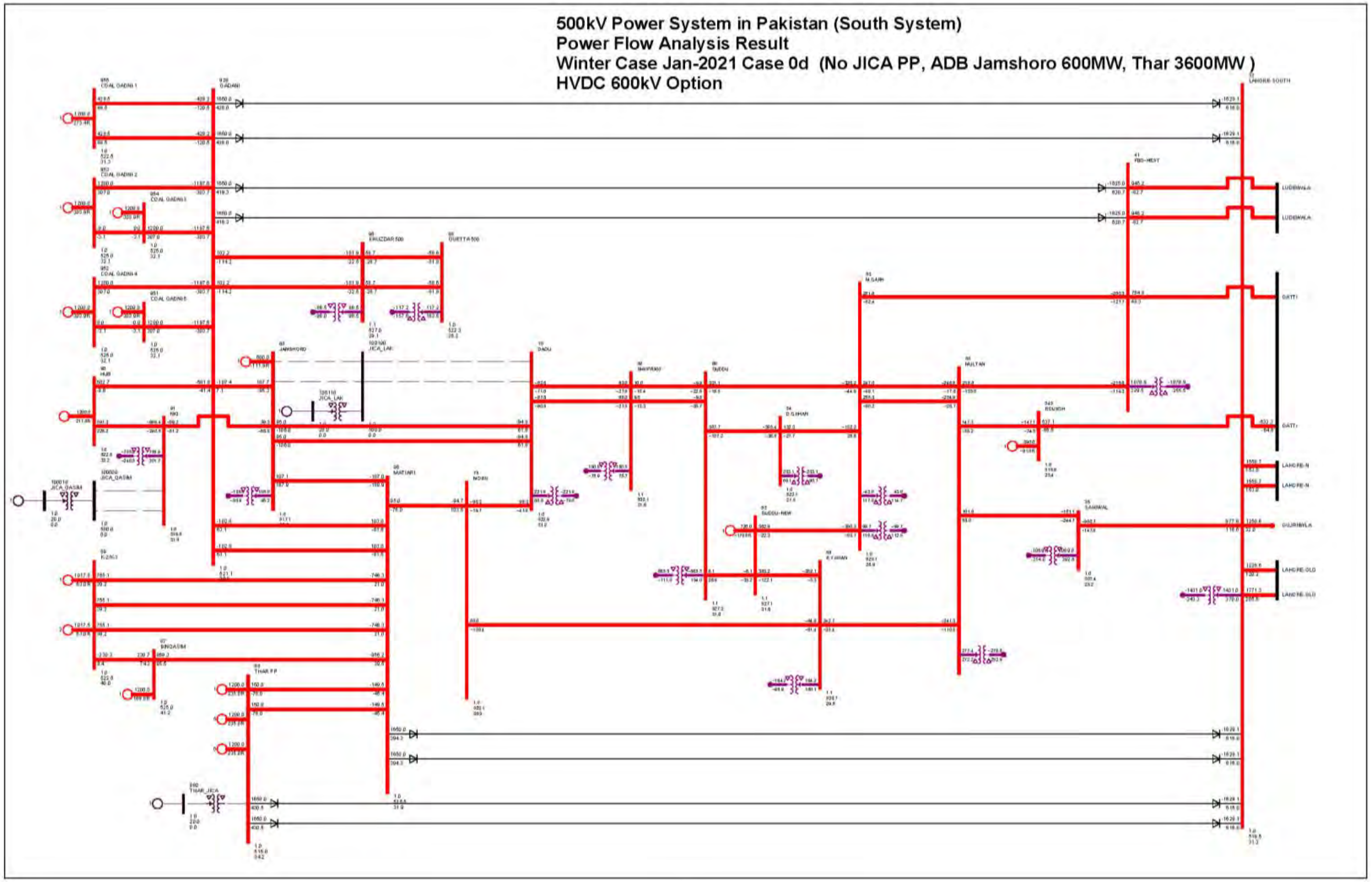
Name	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
LESCO	4,062	4,326	4,478	4,649	4,855	5,063	5,271	5,493	5,736	5,976	6,210
GEPCO	1,994	2,093	2,198	2,324	2,439	2,560	2,686	2,818	2,957	3,102	3,254
FESCO	2,812	3,013	3,216	3,427	3,651	3,886	4,167	4,480	4,807	5,127	5,450
IESCO	2,285	2,389	2,481	2,621	2,754	2,894	3,047	3,201	3,354	3,509	3,669
MEPCO	3,106	3,299	3,449	3,736	3,949	4,170	4,399	4,636	4,894	5,161	5,438
PESCO	2,626	2,645	2,754	2,865	2,976	3,089	3,202	3,316	3,431	3,547	3,663
HESCO	1,350	1,421	1,496	1,574	1,656	1,742	1,831	1,926	2,024	2,128	2,236
QESCO	1,245	1,288	1,332	1,337	1,425	1,474	1,525	1,579	1,635	1,693	1,753
TESCO	622	641	662	682	704	726	750	774	799	825	852
SEPCO	1,019	1,070	1,122	1,176	1,232	1,290	1,350	1,412	1,476	1,542	1,611
DISCO Demand (Diversified)	18,592	19,545	20,473	21,523	22,590	23,695	24,871	26,112	27,412	28,730	30,075
T & T Losses	593	626	655	689	723	759	796	836	878	920	963
% T & T Losses	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*	*3.05*
NTDC Demand	19,121	20,171	21,129	22,212	23,313	24,453	25,667	26,948	28,290	29,649	31,038
Auxiliary Consumption	327	345	361	380	398	418	439	460	483	507	530
% Auxiliary Consumption	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*	*1.68*
Total Demand without export to KESC	19,448	20,516	21,490	22,592	23,711	24,871	26,105	27,408	28,773	30,156	31,568

3 - 1 POWER SYSTEM ANALYSIS

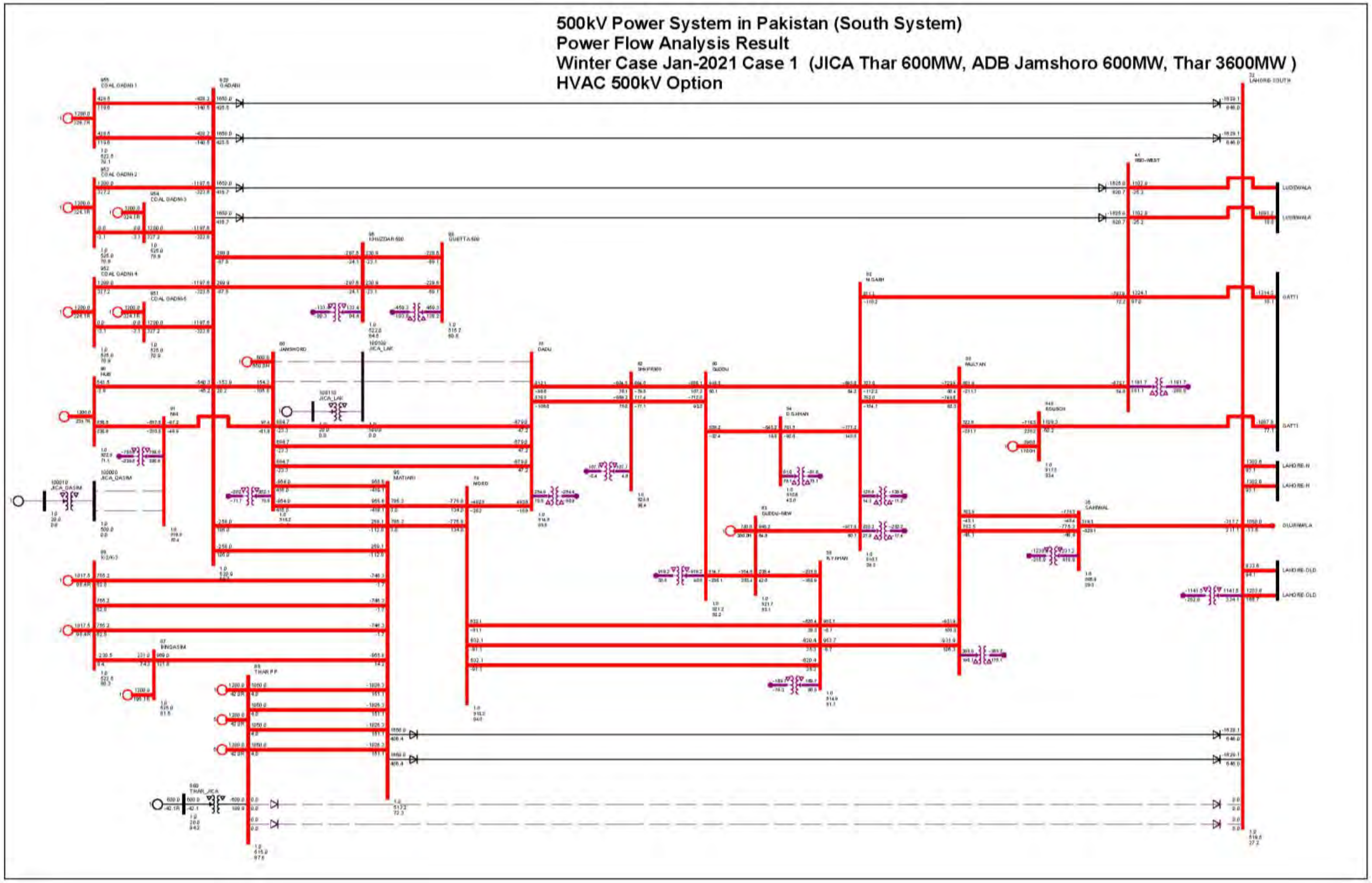
Power System Analysis



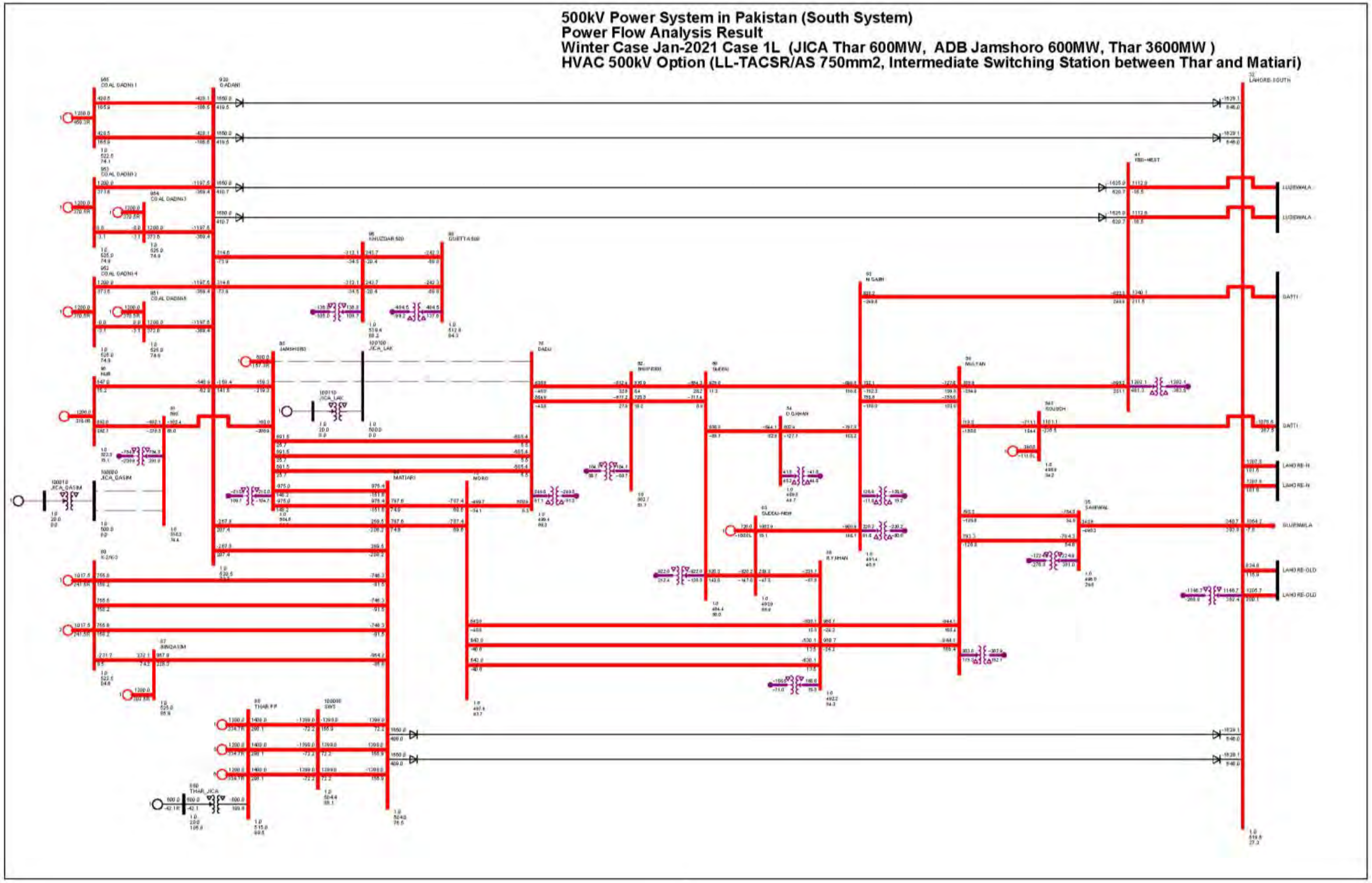
Power System Analysis



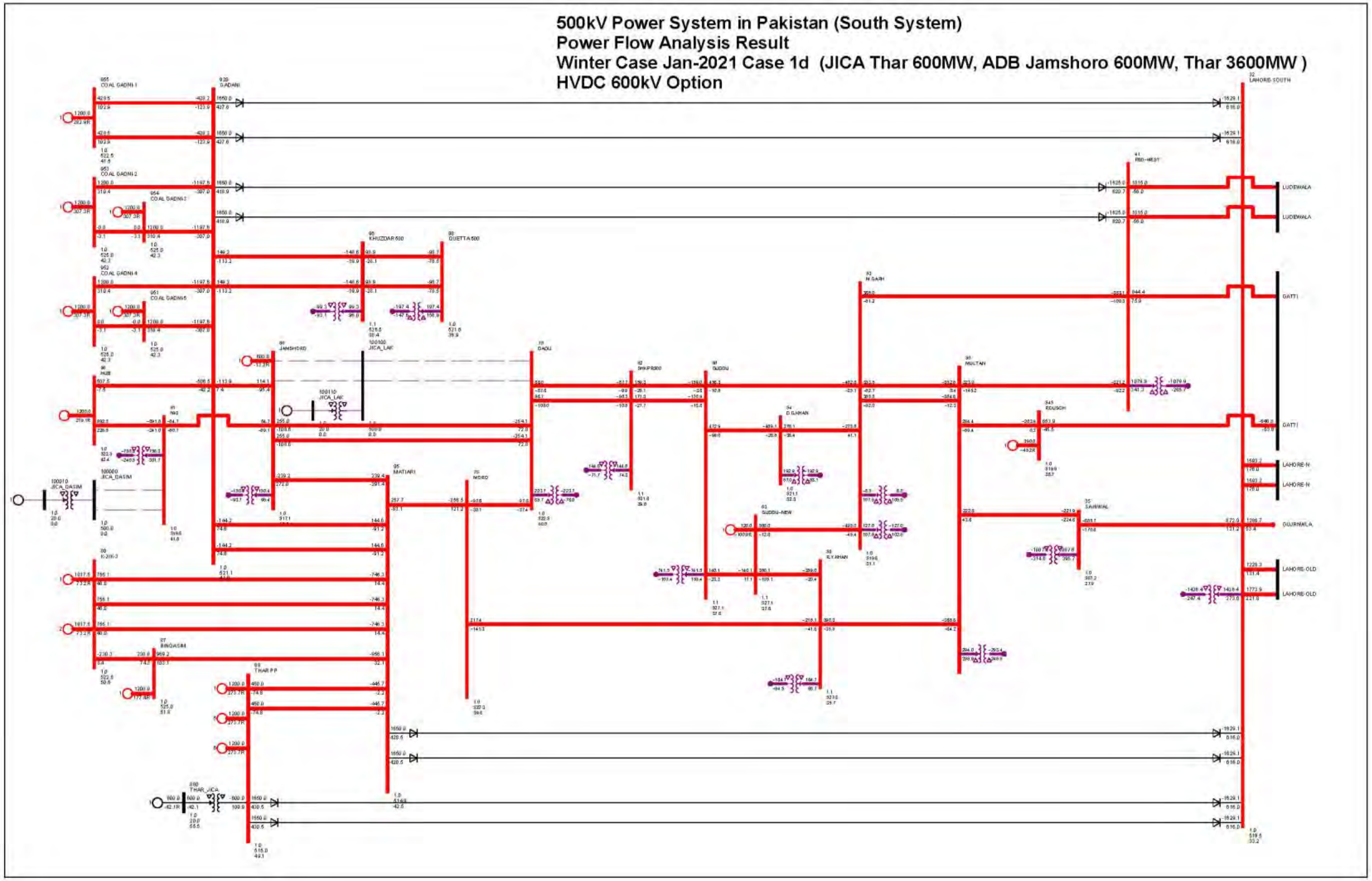
Power System Analysis



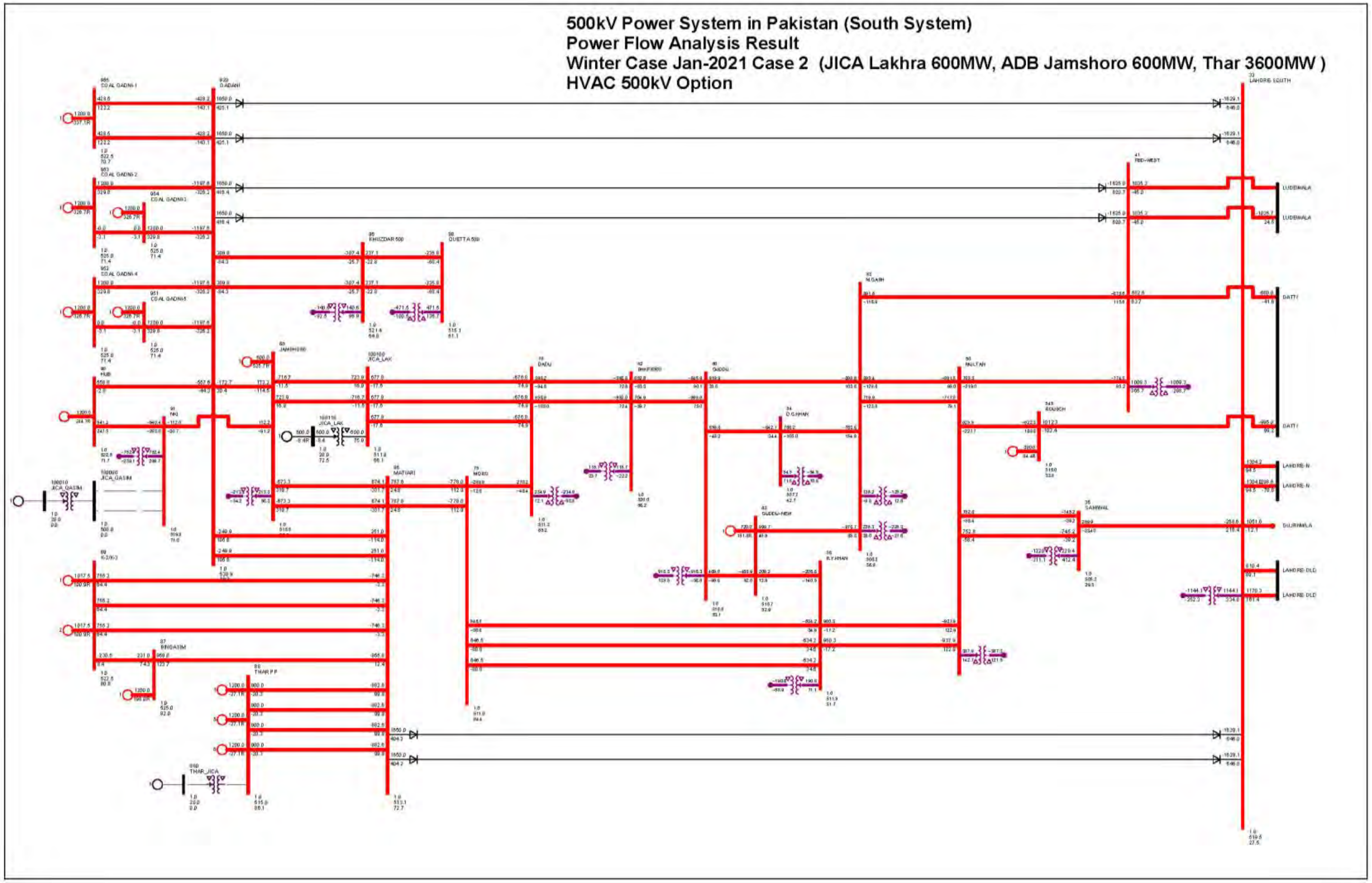
Power System Analysis



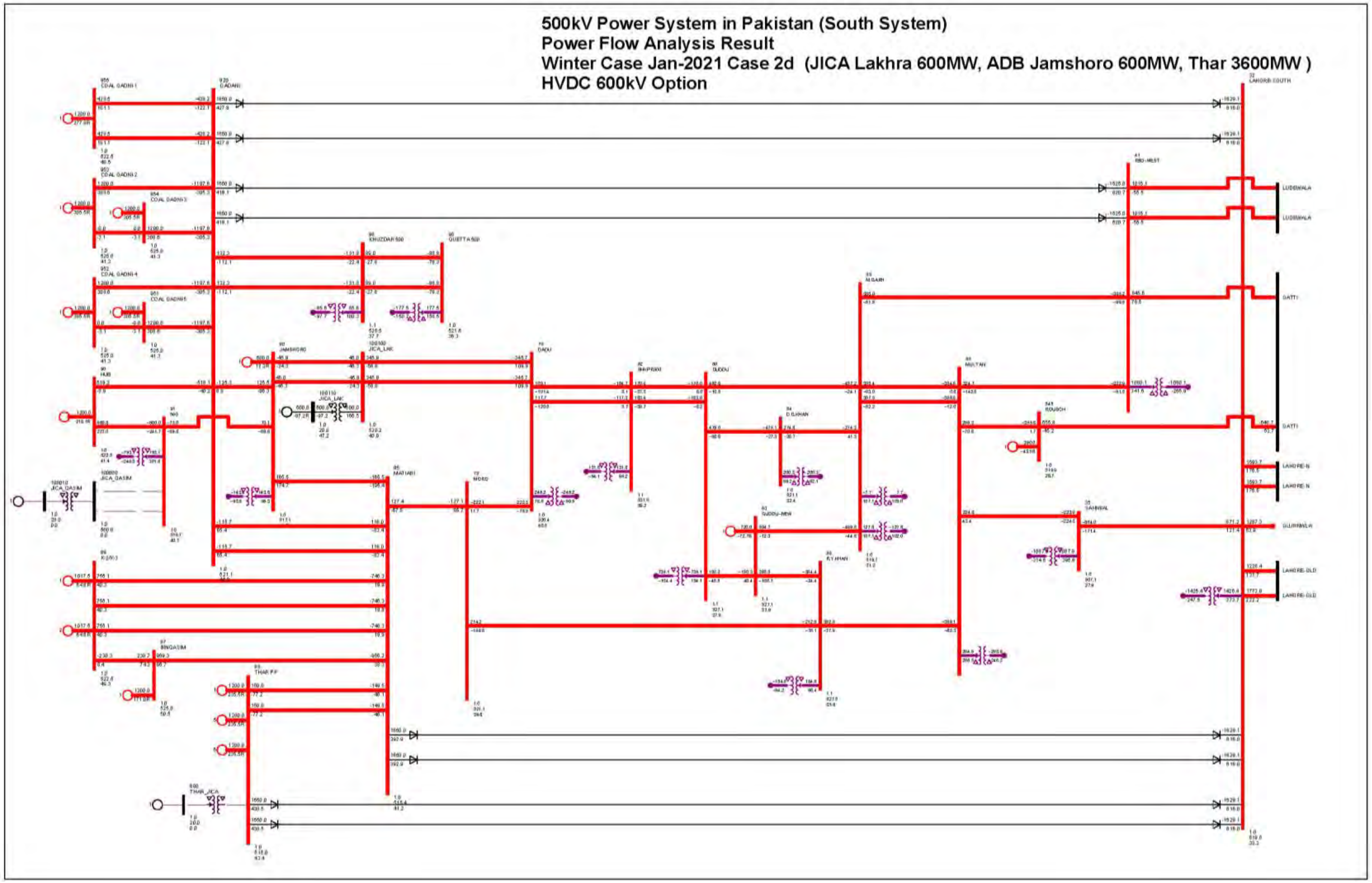
Power System Analysis



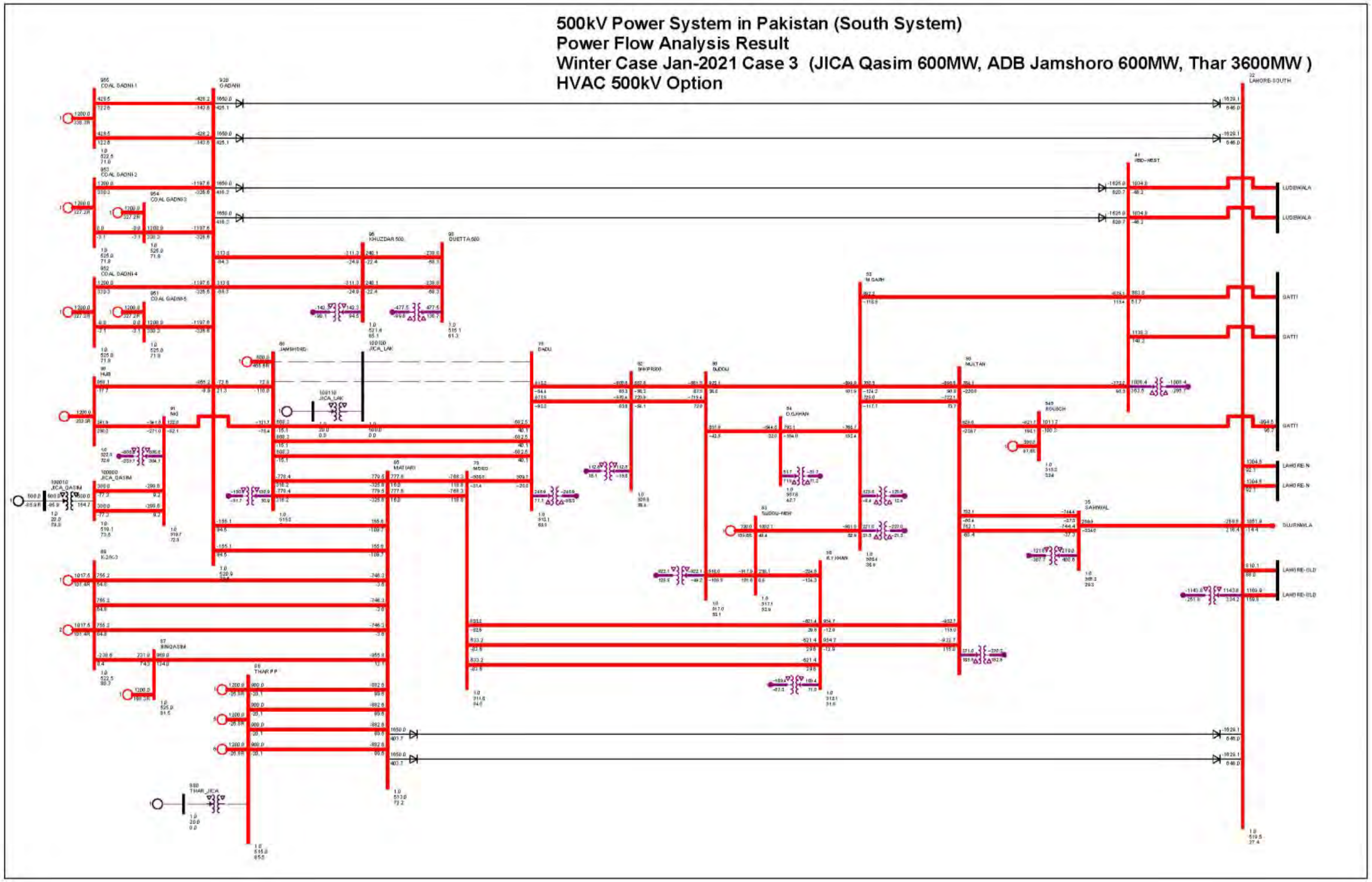
Power System Analysis



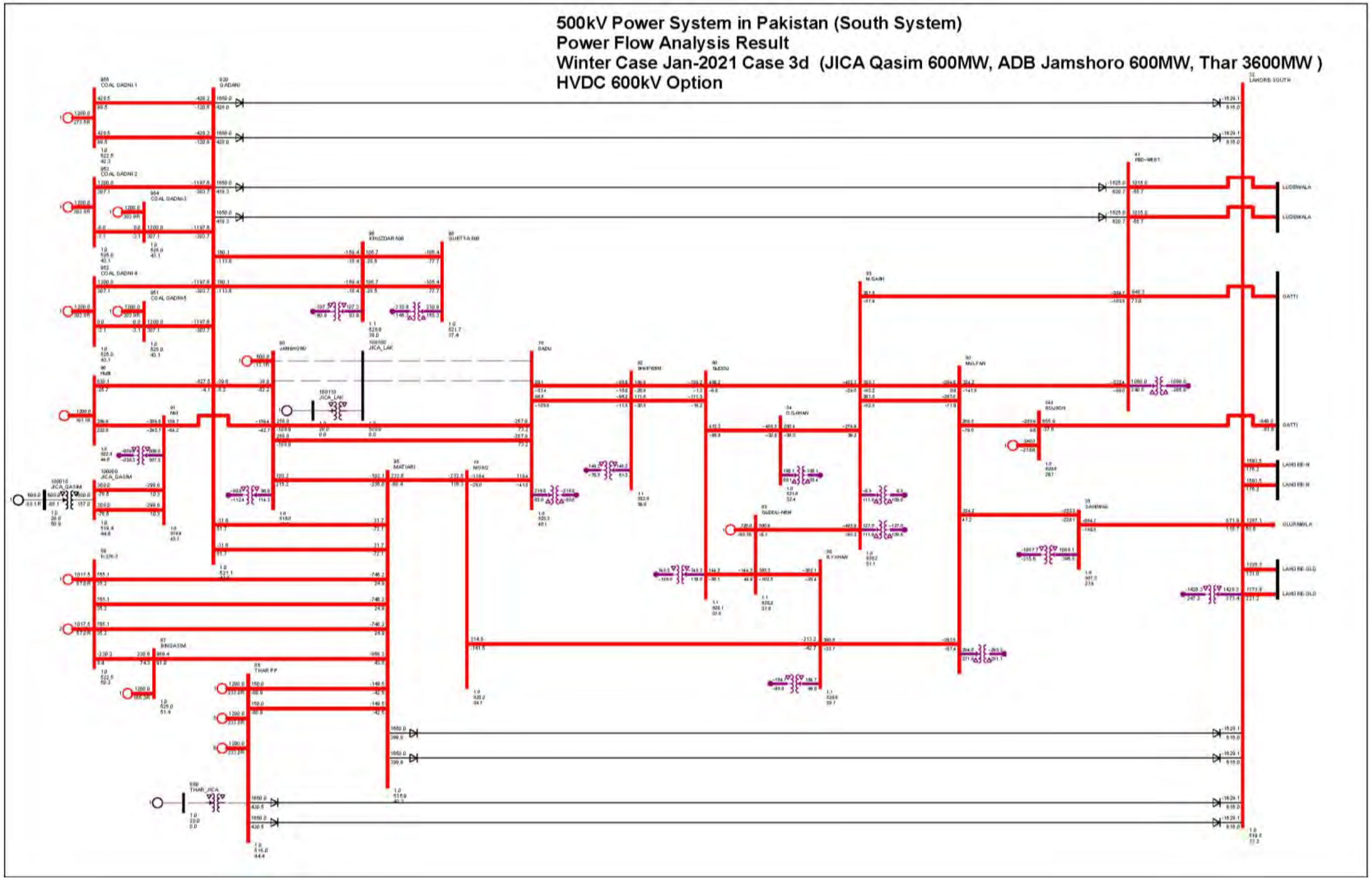
Power System Analysis



Power System Analysis



Power System Analysis



3 - 2 TRANSIENT STABILITY ANALYSIS

Transient Stability Analysis

Transient stability analysis on the NTDC power system in 2020 was conducted in order to confirm if the power system maintains the transient stability under the severe fault conditions.

Study Conditions

The transient stability analysis was carried out under the following conditions:

- Target year of study is 2020, the expected year of commercial operation of CFPP proposed by this study.
- Same case files for each CFPP location option as those used for the power flow analysis were used for the transient stability analysis.
- Dynamic data for the planned power plants except for that for CFPP proposed by JICA Survey Team was provided by NTDC.
- As the generator, exciter, and turbine governor models, the same models as those for the generator with similar unit size were applied to.
- Only Winter Low Water condition was considered for the analysis since the power flow from the thermal power plants planned in the southern part of Pakistan is considered dominant in the period, thus being severer condition for the southern system.
- Only 500kV HVAC system was considered for each CFPP location option since the power flow of the transmission lines in the southern system was resulted in larger than that for 500kV HVDC system option.
- The power system stabilizer (PSS) was not applied to the generators for the planned power plants.

Study Cases

If the generators in the southern system can maintain stable synchronous operation even when the system component fault occurs, the power system is regarded as stable. The criterion, “when the phase angle differences of the generator rotors between arbitrary two power plants are likely to converge, the power system is considered stable”, was set out to evaluate the analysis results.

As the severest single contingency conditions, a single circuit 3-phase short circuit fault at the sending end of the 500kV transmission lines with the following conditions were selected:

- 500kV transmission lines from the candidate CFPP location
- Relatively heavily loaded 500kV transmission lines which are reinforced from NTDC’s original power system plan

Transient Stability Analysis

The study cases and the fault section of the transmission lines are summarized in Table 3. 2-1 The cells with “Y” indicate that the fault sections are applicable to the cases.

Table A3.2-1 Study Cases

Fault Section \ Case	Case 0 (No CFPP Case)	Case 1 (Thar Case, AAAC)	Case 1L (Thar Case, LL + SWS)	Case 2 (Jamshoro /Lakhra Case)	Case 3 (Qasim Case)
Thar PP - Matiari	Y	Y		Y	Y
Thar - Switching Station			Y		
Matiari - Jamshoro	Y	Y	Y	Y	Y
Jamshoro - Dadu	Y	Y	Y		Y
Matiari - Moro	Y	Y	Y	Y	Y
Dadu - Moro	Y	Y	Y	Y	Y
Moro - R. Y. Khan	Y	Y	Y	Y	Y
Jamshoro - JICA Lakhra PP				Y	
JICA Lakhra PP - Dadu				Y	
JICA Qasim PP - NKI					Y

Source: JICA Survey Team

The fault sequence for the analysis is shown in Table A3.2-2.

Table A3.2-2 Fault Sequence

Time	Sequence
0 ms	3-phase short circuit fault occurred to a circuit of 500kV transmission line
100 ms	Clear fault and open the faulted circuit
10 s	End of calculation

Source: JICA Survey Team

Study Results

The oscillation waveforms of phase angle difference between a generator of HUBCO power station and other principal generators for all cases were shown in Appendix 3.3-3. The results are summarized in Table A3.2-4.

Transient Stability Analysis

Table A3.2-4 Transient Stability Analysis Results

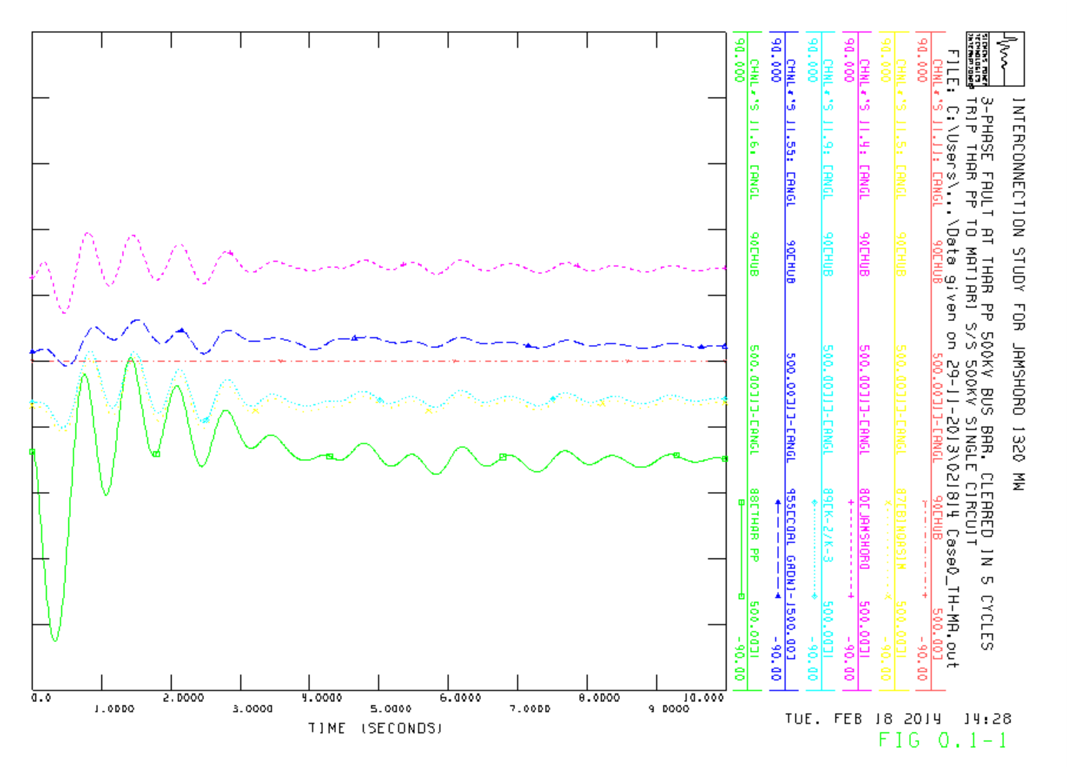
Fault Section \ Case	Case 0 (No CFPP Case)	Case 1 (Thar Case, AAAC)	Case 1L (Thar Case, LL + SWS)	Case 2 (Jamshoro /Lakhra Case)	Case 3 (Qasim Case)
Thar PP - Matiari	Stable	Stable		Stable	Stable
Thar - Switching Station			Stable		
Matiari - Jamshoro	Stable	Stable	Stable	Stable	Stable
Jamshoro - Dadu	Stable	Stable	Stable		Stable
Matiari - Moro	Stable	Stable	Stable	Stable	Stable
Dadu - Moro	Stable	Stable	Stable	Stable	Stable
Moro - R. Y. Khan	Stable	Stable	Stable	Stable	Stable
Jamshoro - JICA Lakhra PP				Stable	
JICA Lakhra PP - Dadu				Stable	
JICA Qasim PP - NKI					Stable

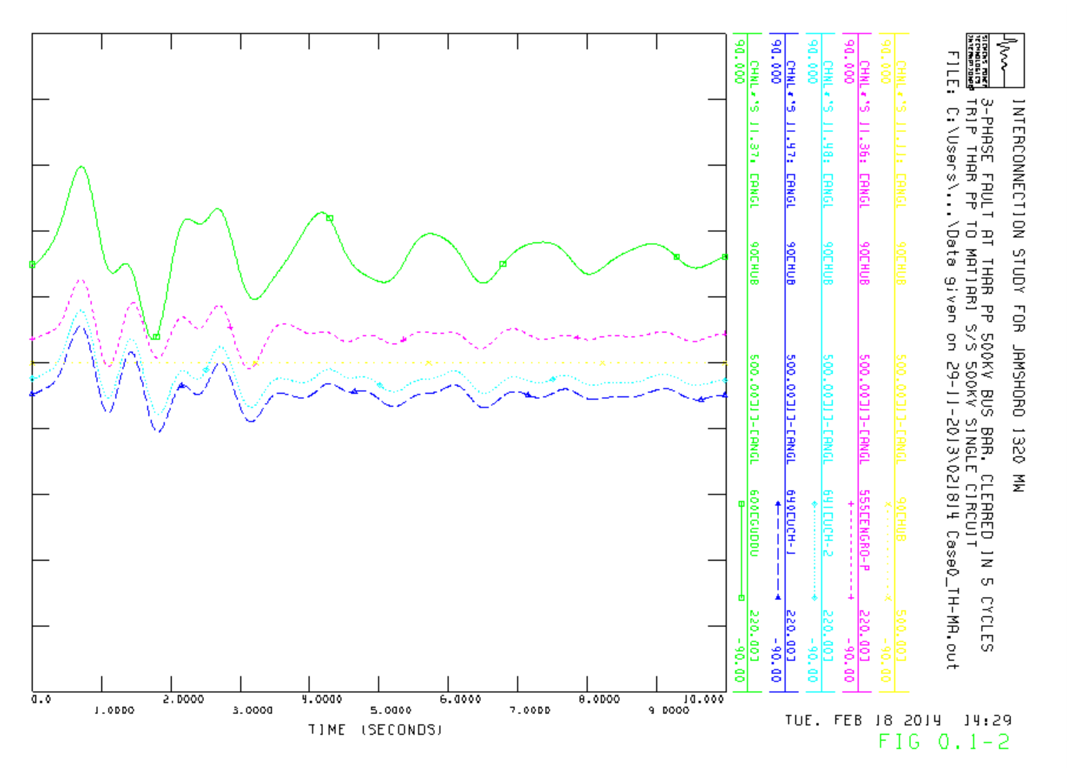
Source: JICA Survey Team

In all cases, the oscillation waveforms of the phase angle differences at principal power stations in southern system were likely to converge. Therefore, it can be concluded that the transient stability of the southern system is expected to be maintained under the single contingency of the 500kV transmission lines in winter peak load condition in 2020.

3 - 3 STABILITY ANALYSIS SRSULTS FOR YEAR 2020 (LOW WATER JANUARY 2021)

Transient Stability Analysis





Case 0 (No CFPP Case) Fault Section: Thar CFPP – Matiari S/S

Transient Stability Analysis

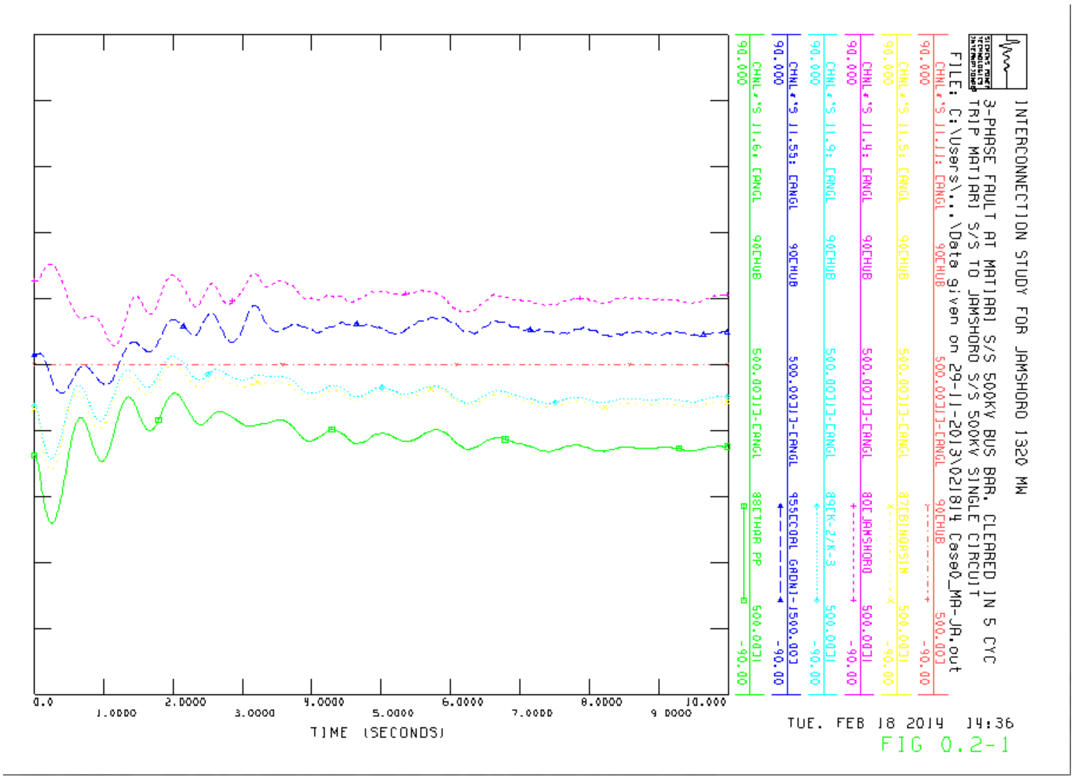


FIG 0.2-1

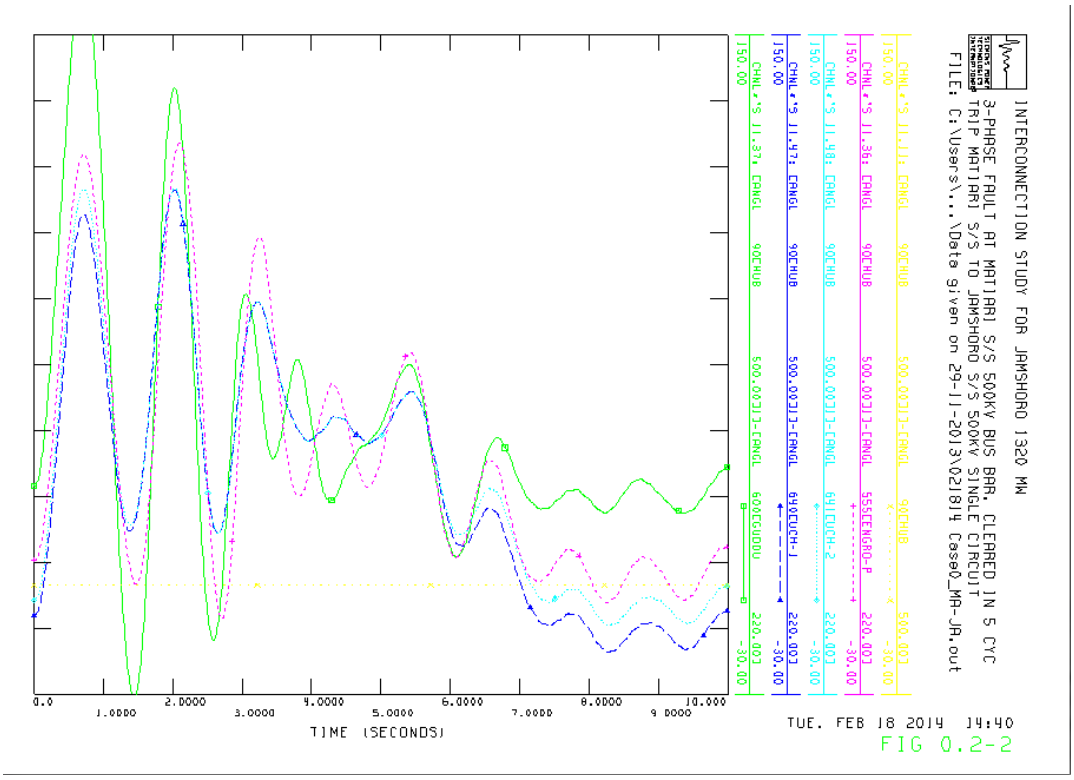
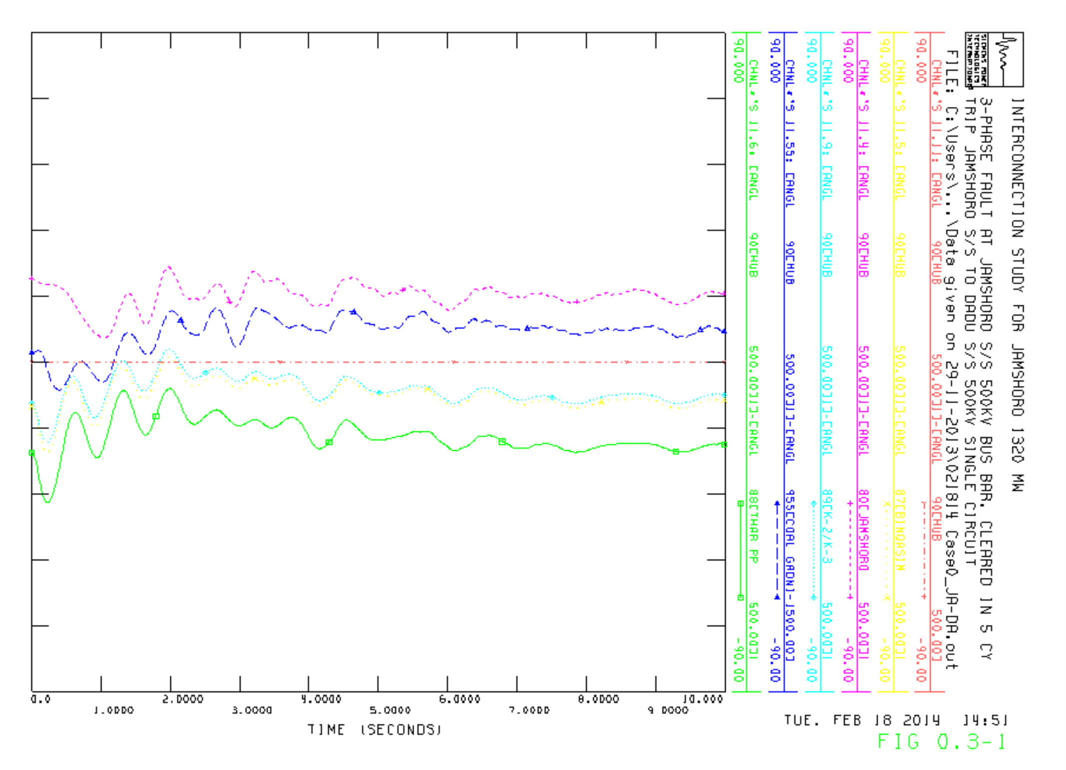
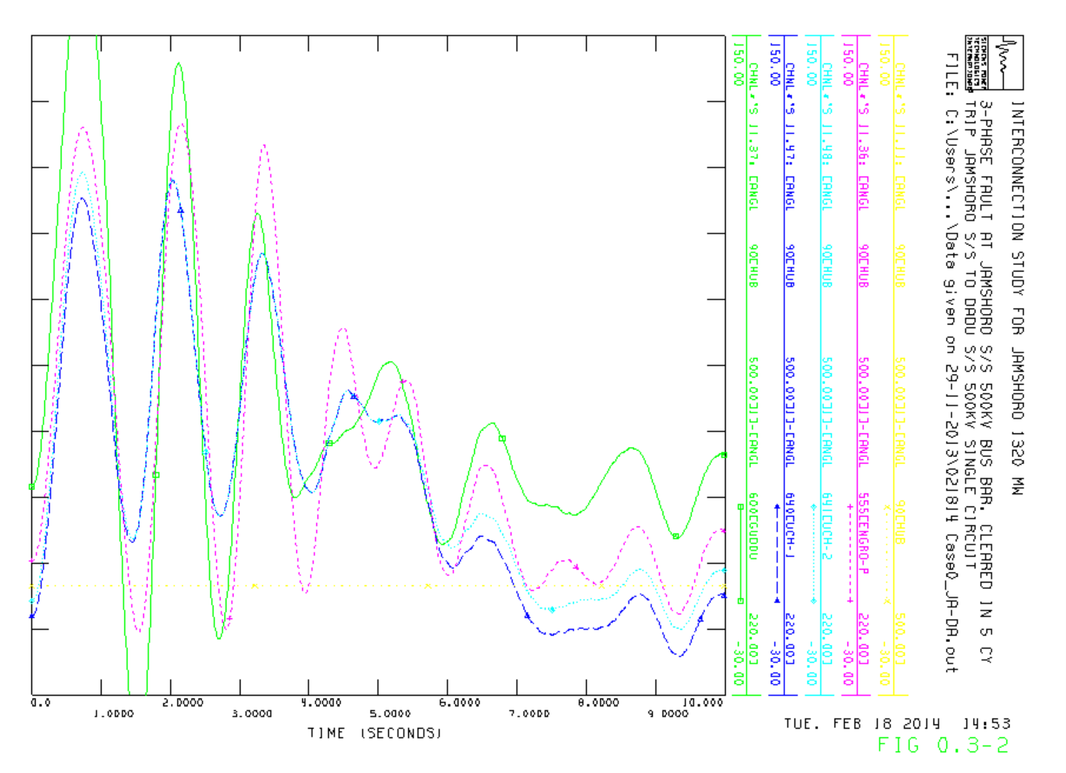


FIG 0.2-2

Case 0 (No CFPP Case) Fault Section: Matiari S/S – Jamshoro S/S

Transient Stability Analysis





Case 0 (No CFPP Case) Fault Section: Jamshoro S/S – Dadu S/S

Transient Stability Analysis

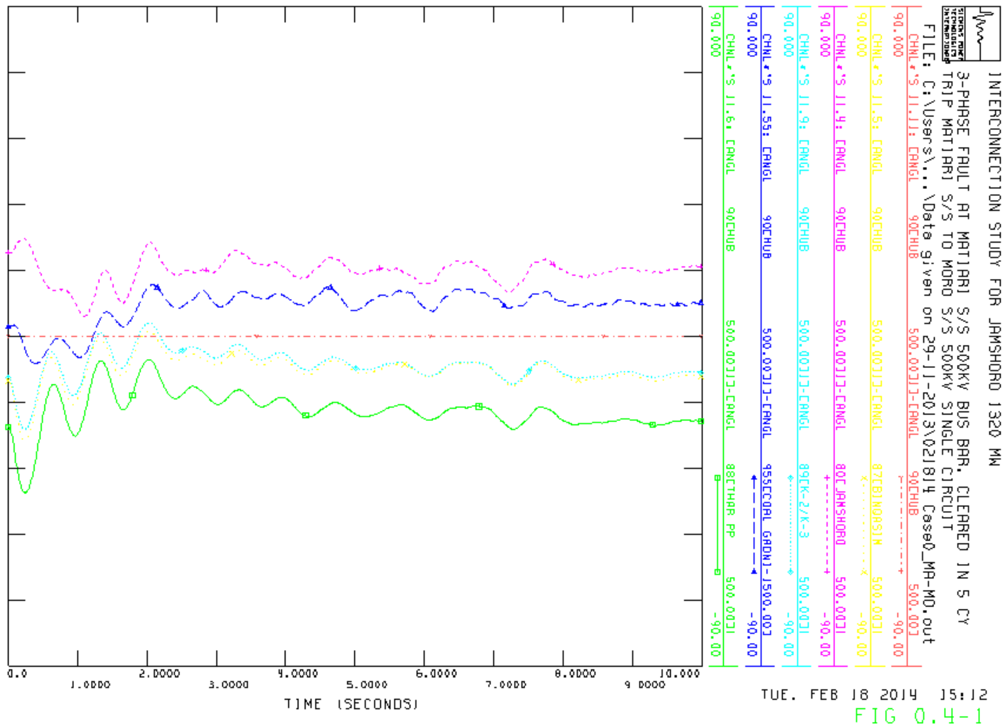


FIG 0.4-1

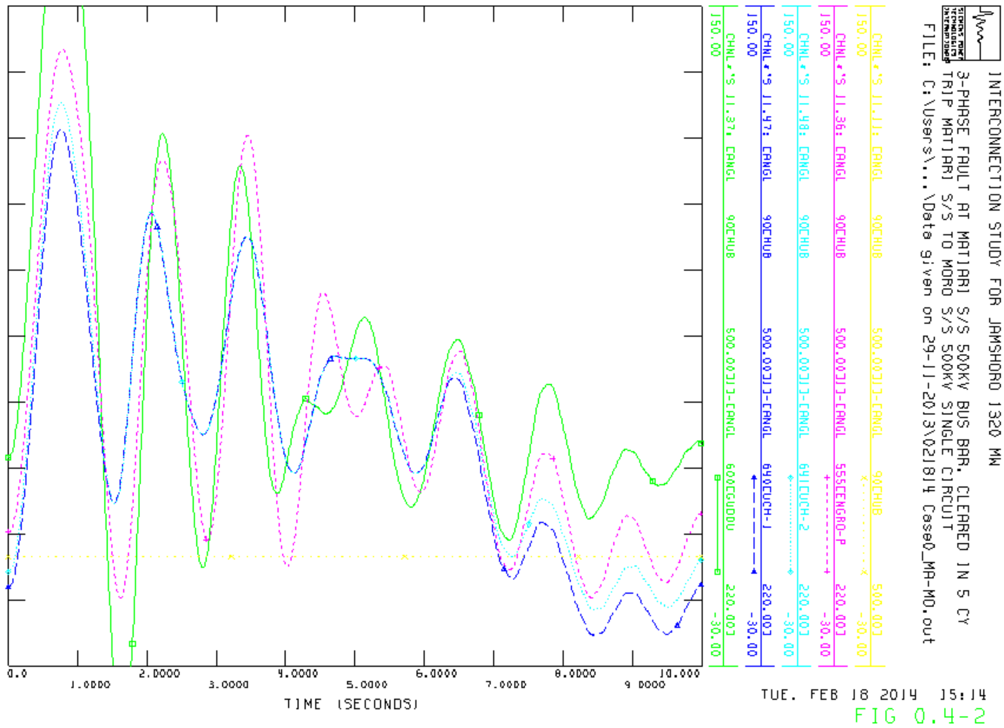
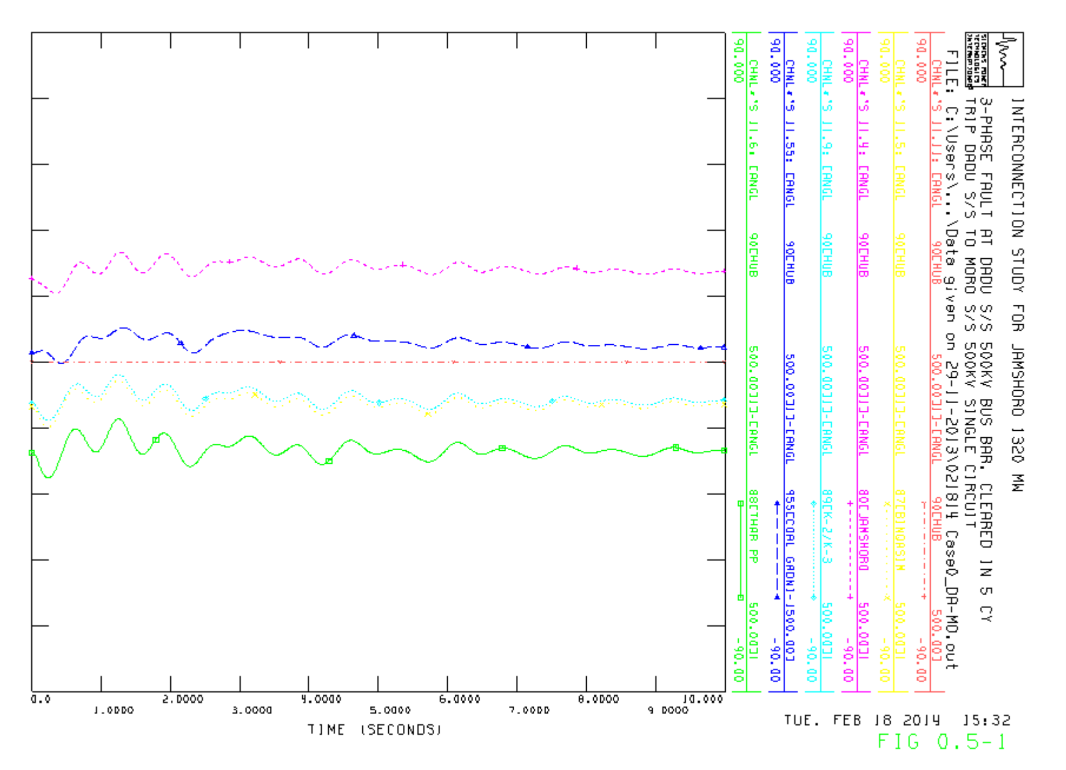
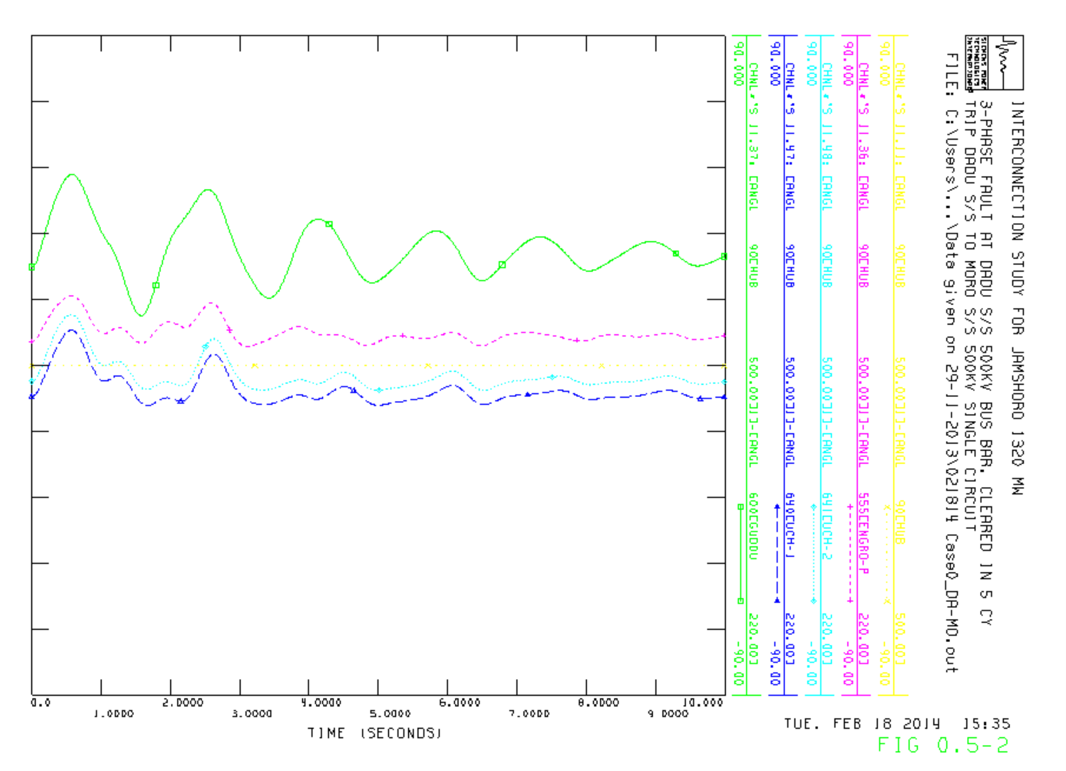


FIG 0.4-2

Case 0 (No CFPP Case) Fault Section: Matiari S/S – Moro S/S

Transient Stability Analysis





Case 0 (No CFPP Case) Fault Section: Dadu S/S – Moro S/S

Transient Stability Analysis

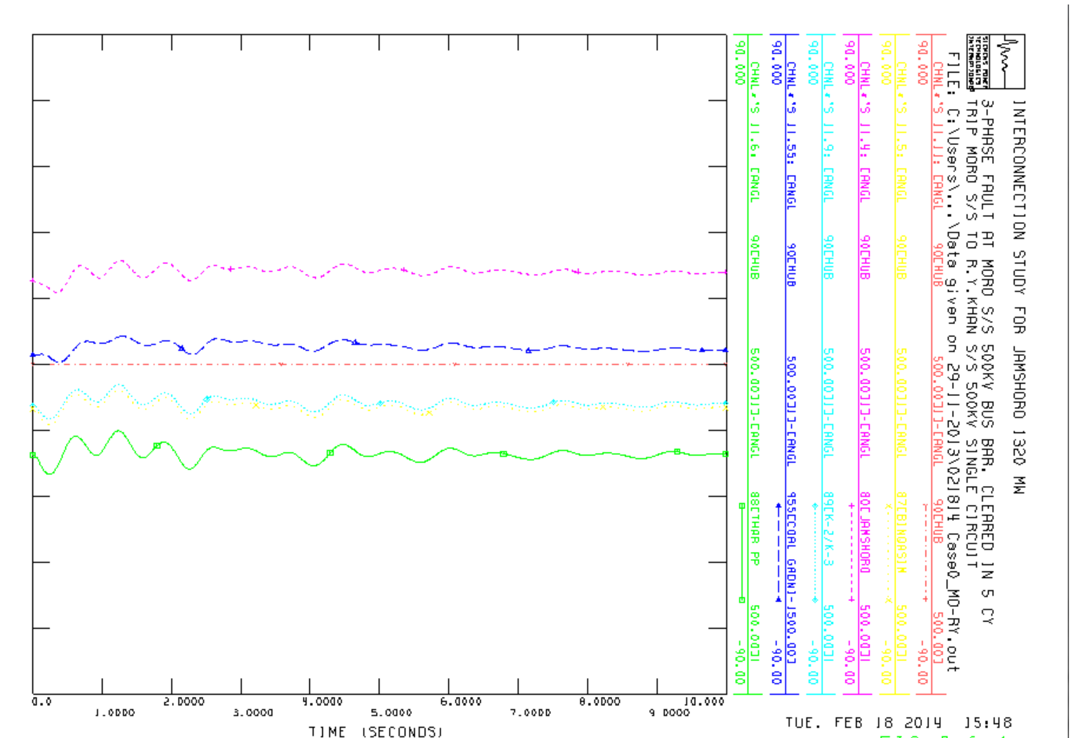


FIG 0.6-1

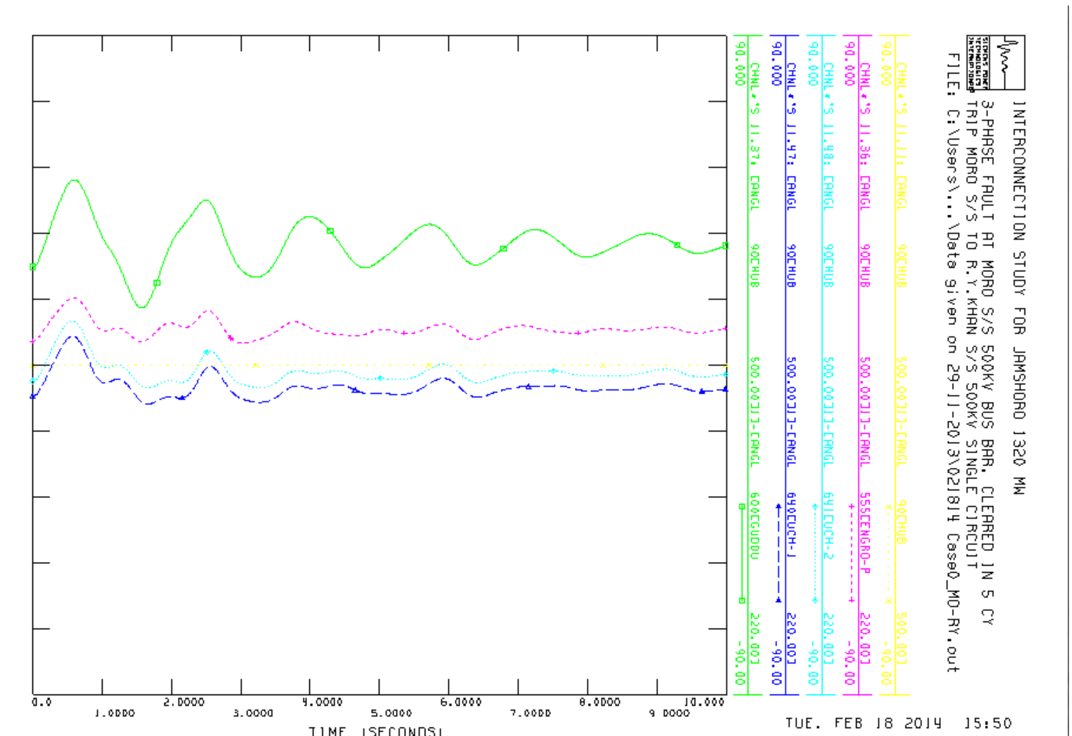
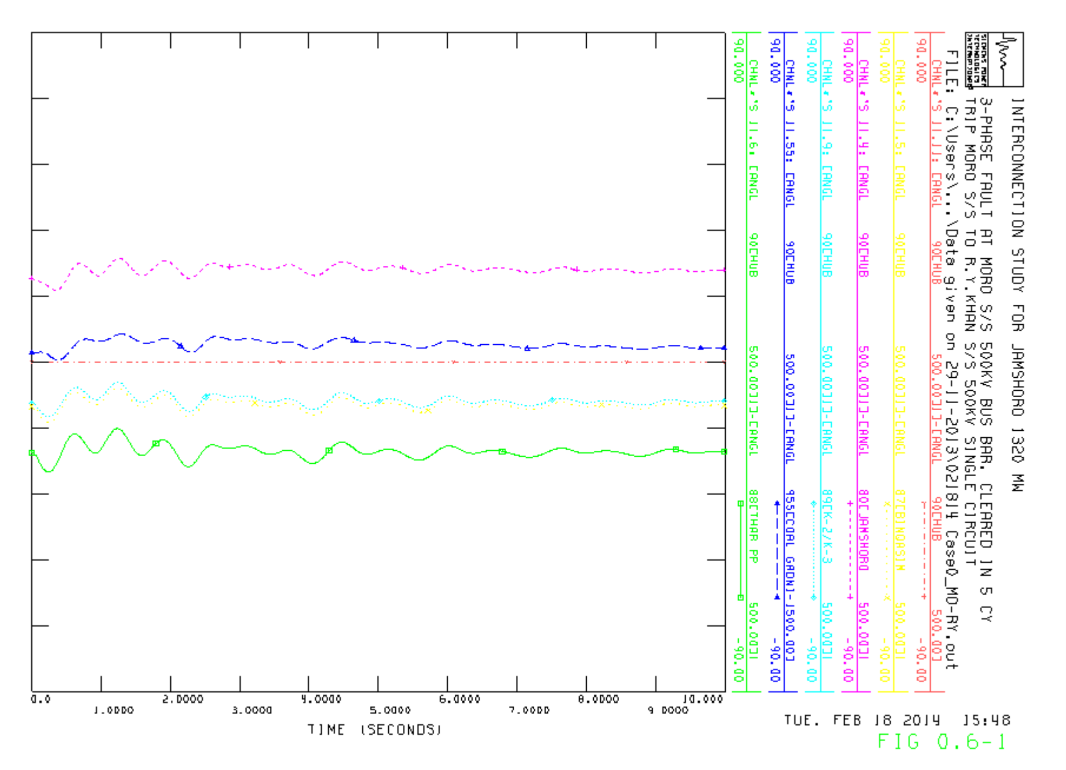
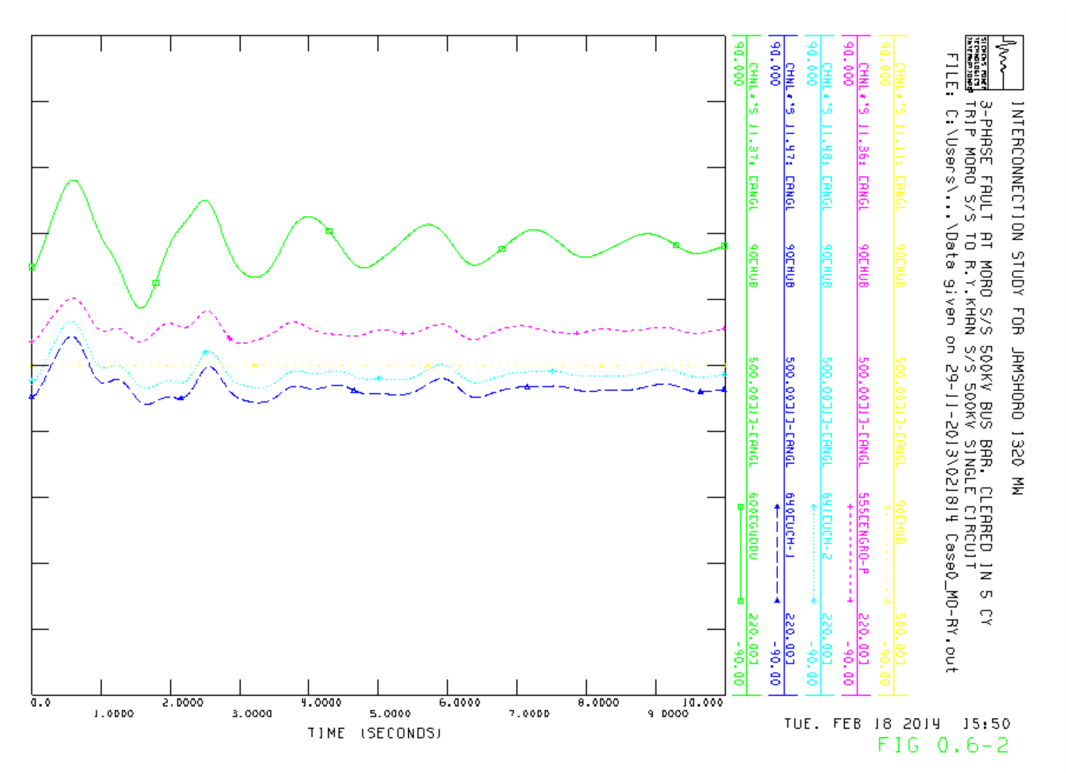


FIG 0.6-2

Case 0 (No CFPP Case) Fault Section: Dadu S/S – Moro S/S

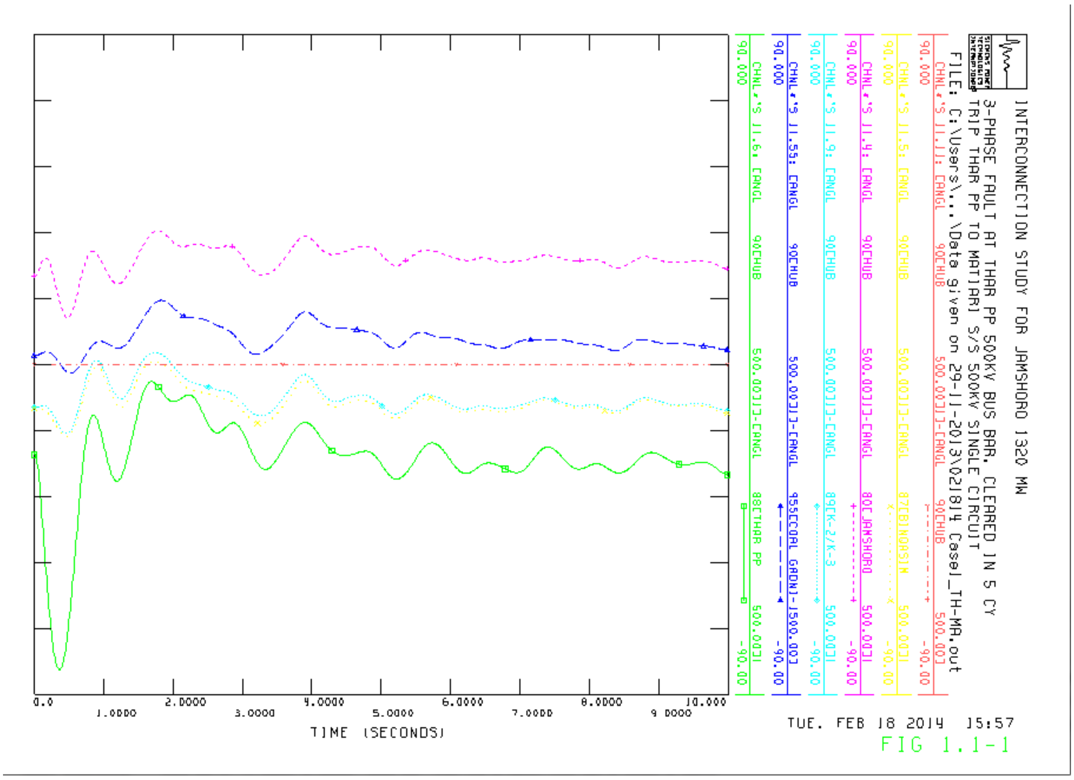
Transient Stability Analysis

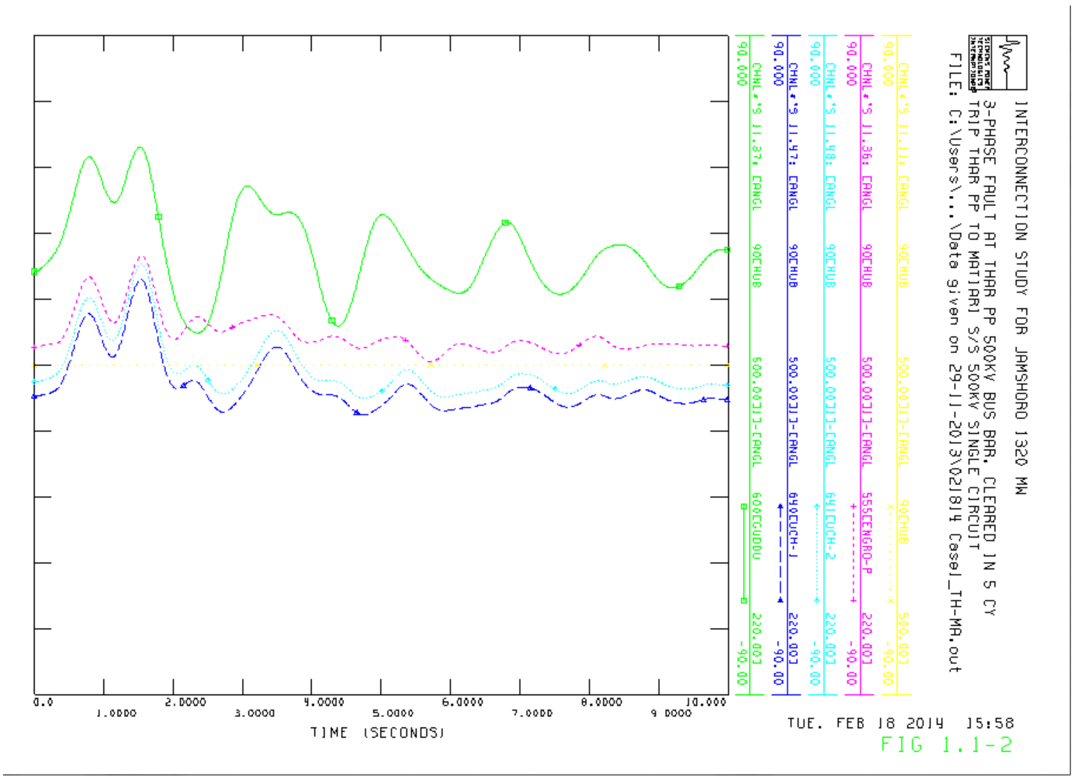




Case 0 (No CFPP Case) Fault Section: Moro S/S – R.Y. Khan S/S

Transient Stability Analysis





Case 1 (Thar Case, AAAC) Fault Section: Thar CFPP – Matiari S/S

Transient Stability Analysis

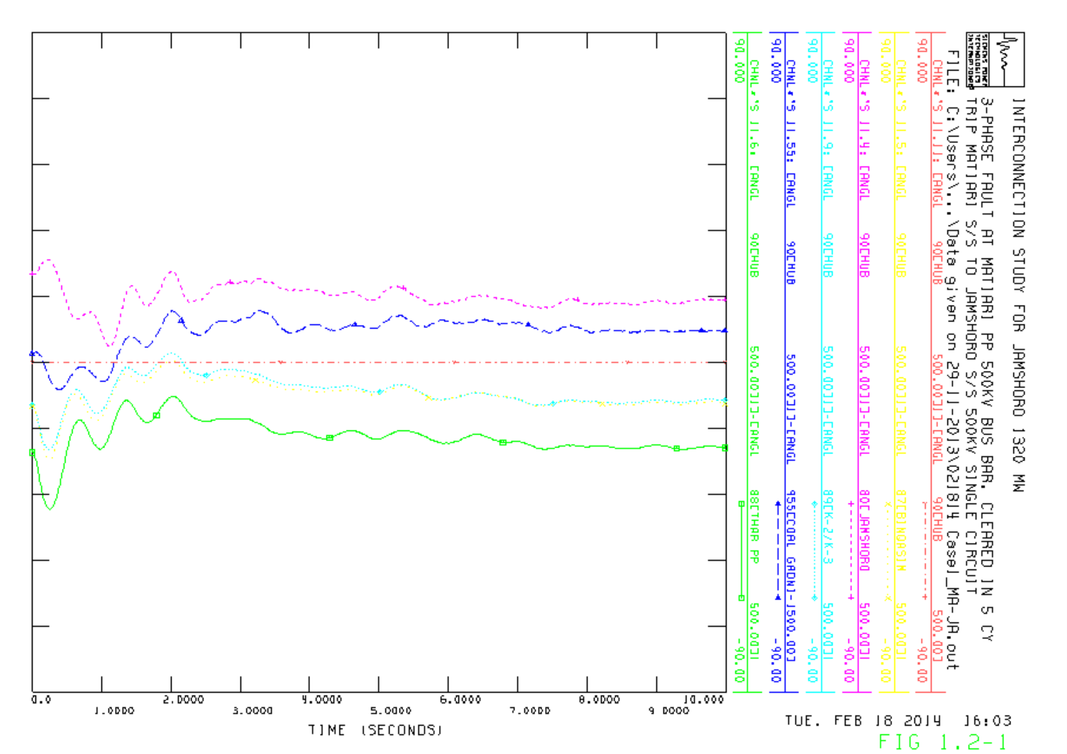


FIG 1.2-1

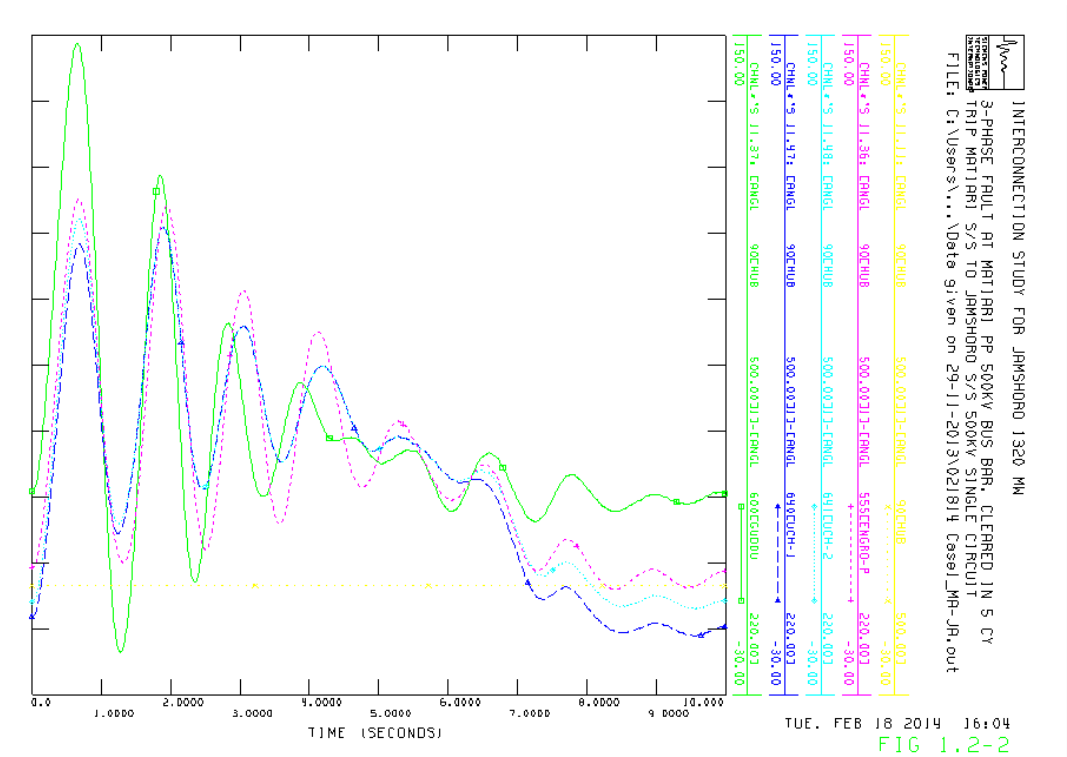
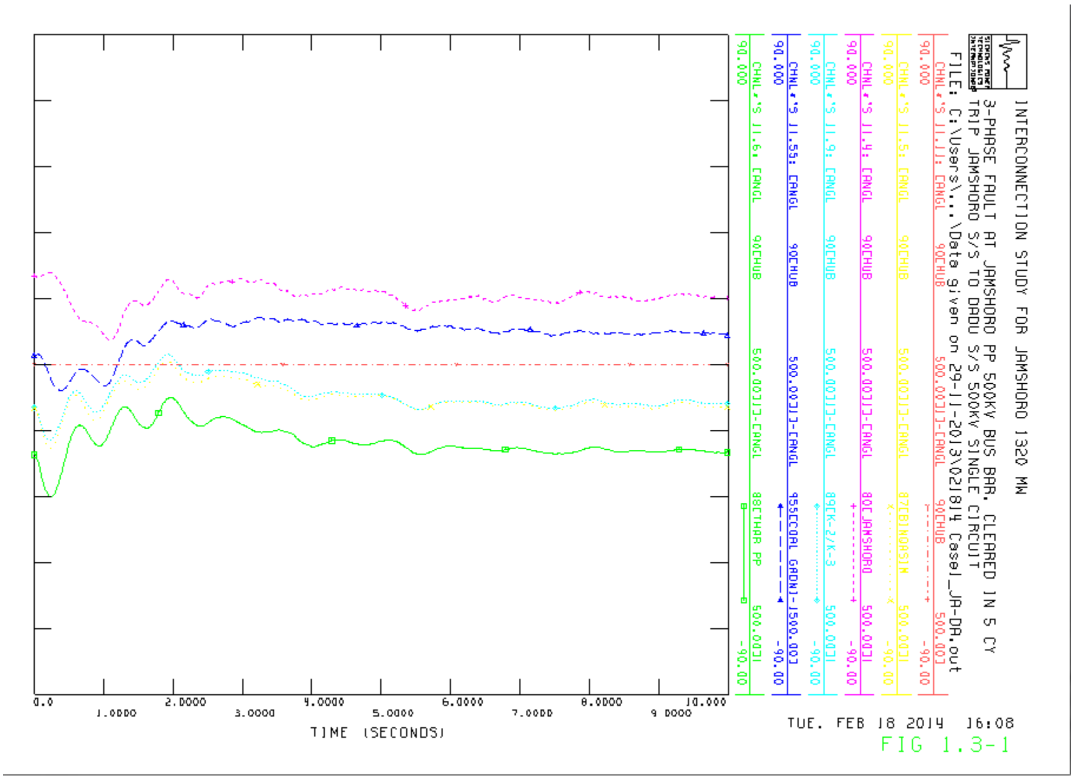
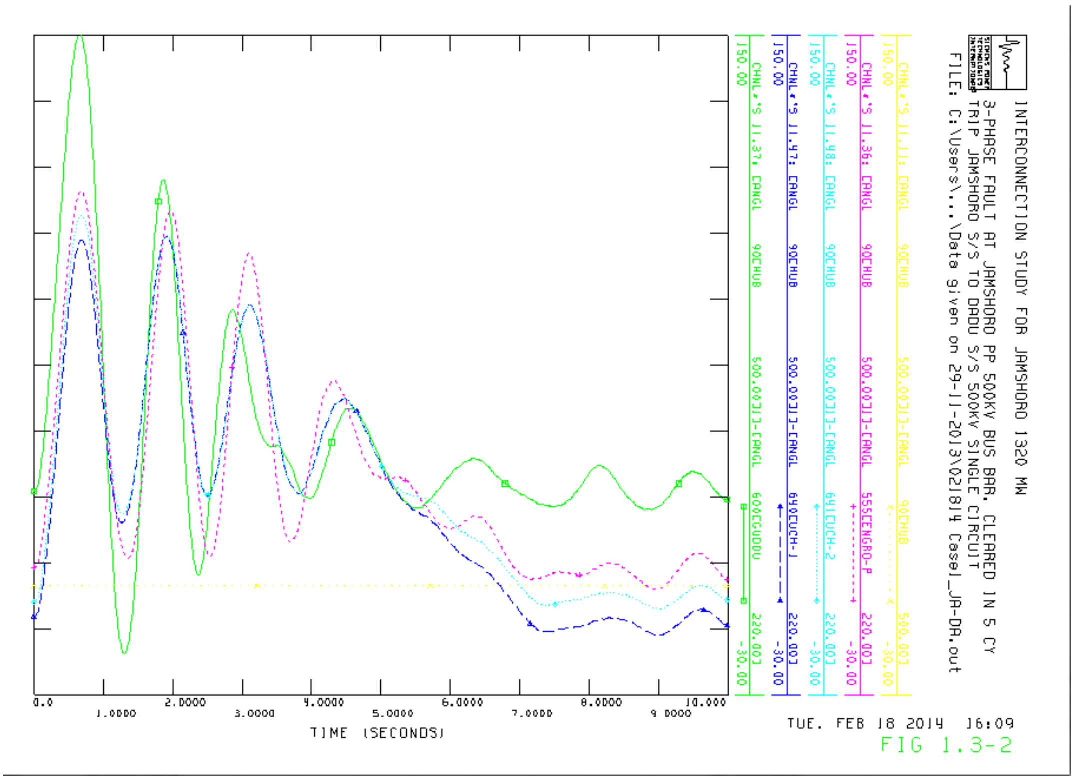


FIG 1.2-2

Case 1 (Thar Case, AAAC) Fault Section: Matiari S/S – Jamshoro S/S

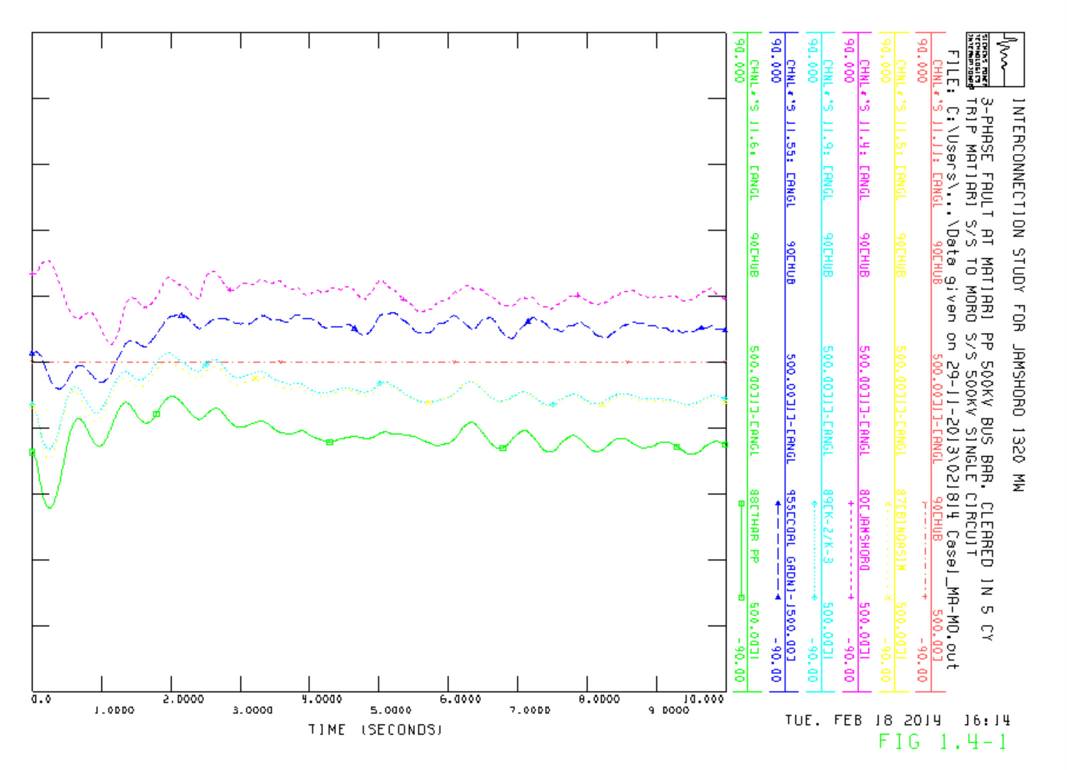
Transient Stability Analysis

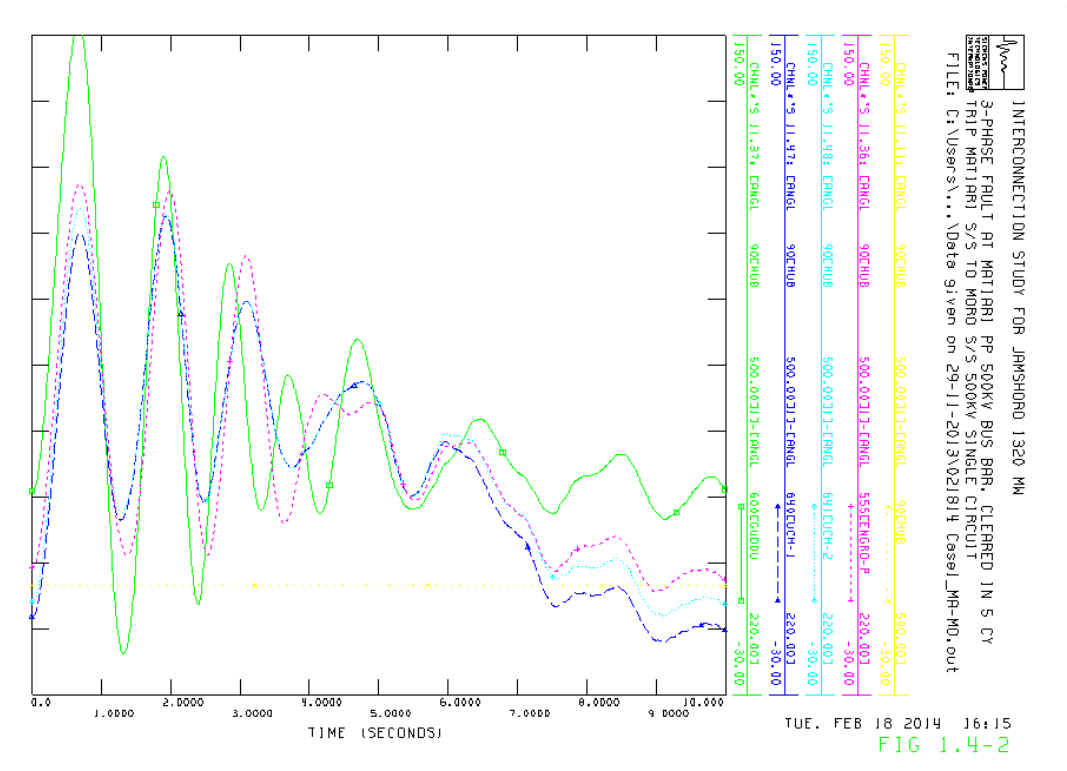




Case 1 (Thar Case, AAAC) Fault Section: Jamshoro S/S – Dadu S/S

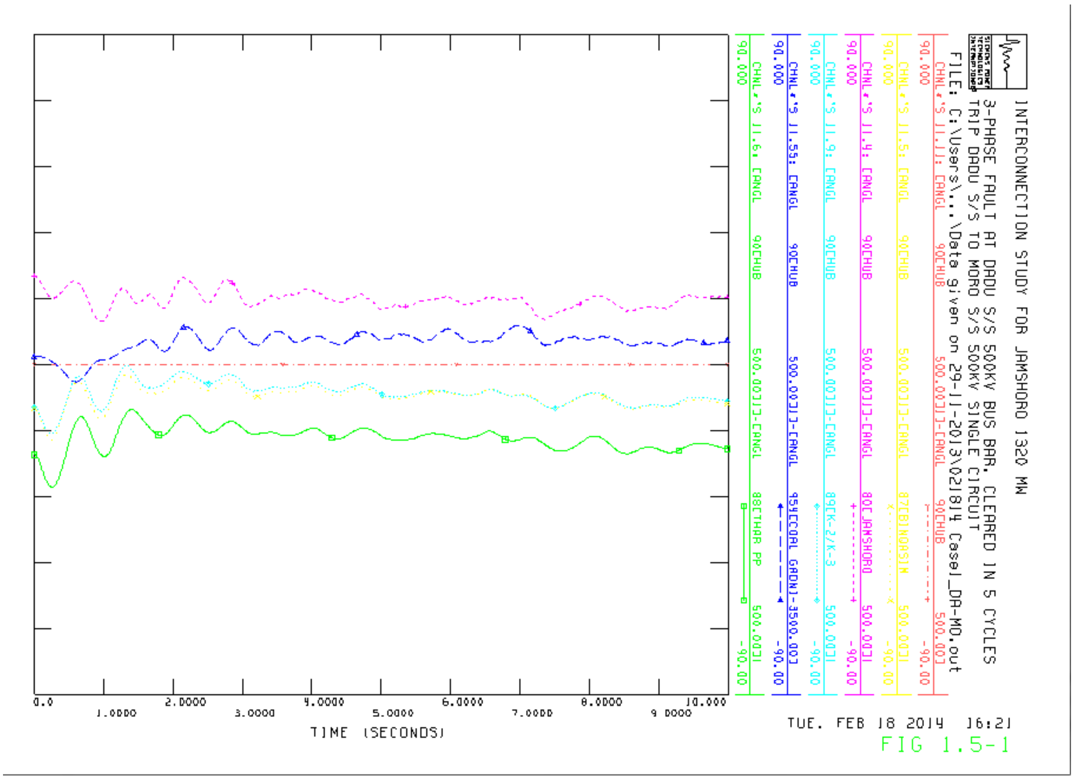
Transient Stability Analysis

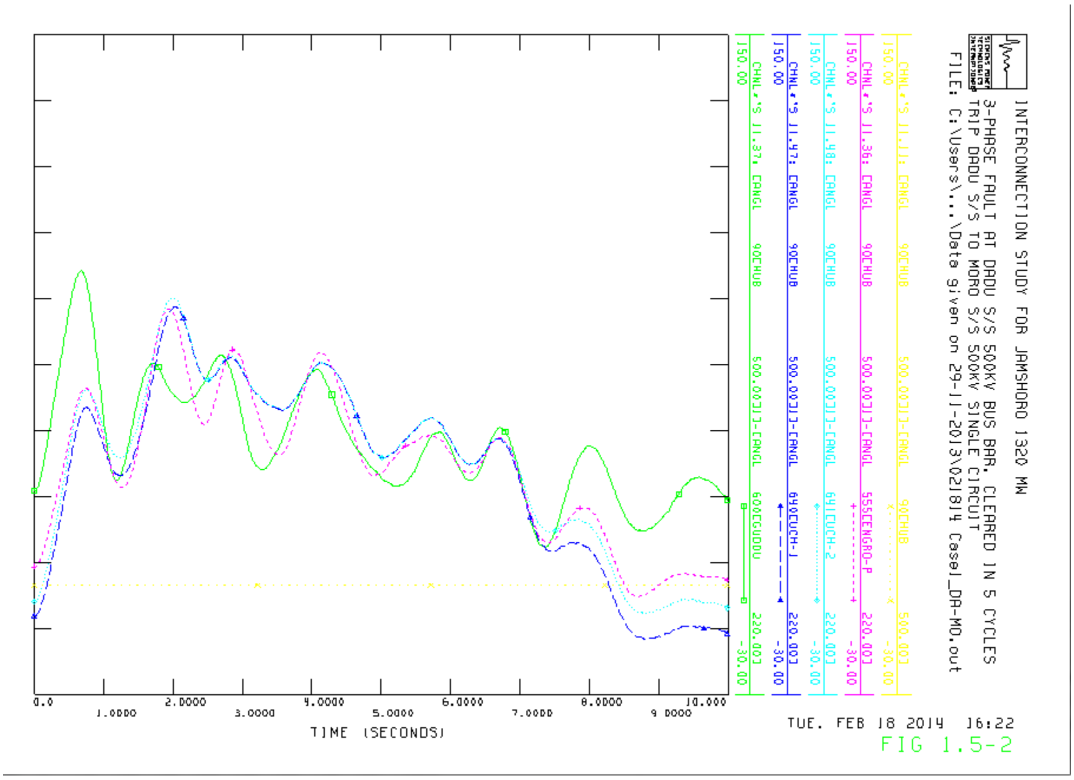




Case 1 (Thar Case, AAAC) Fault Section: Matiari S/S – Moro S/S

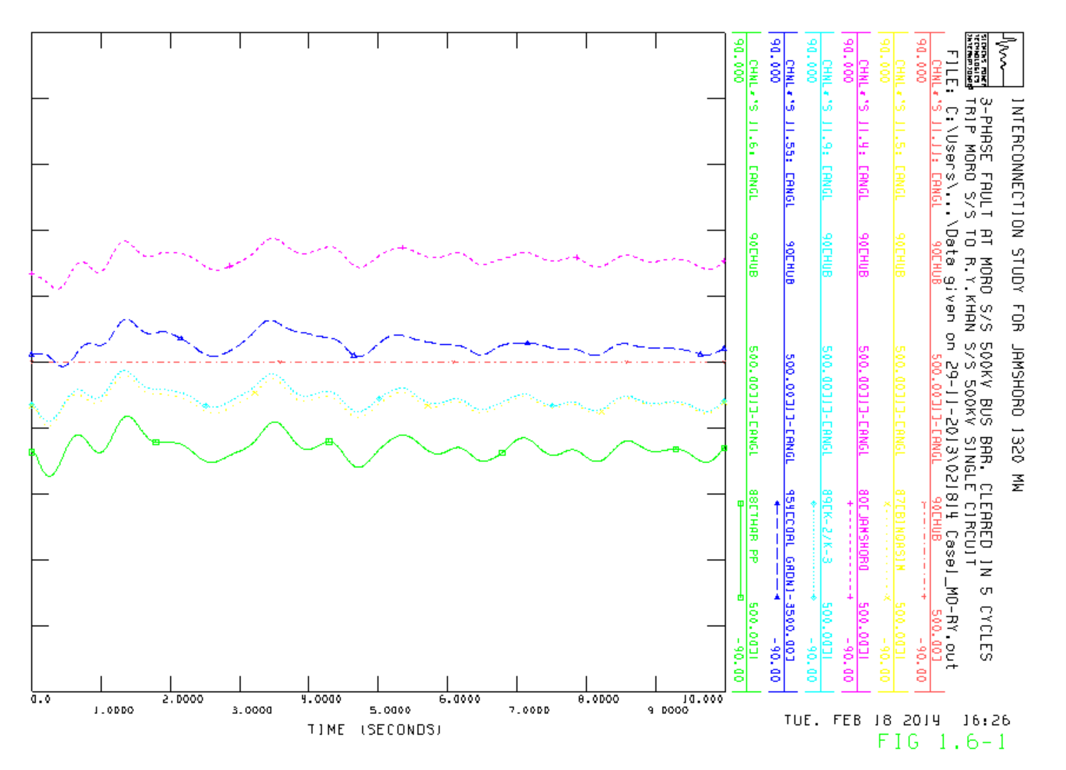
Transient Stability Analysis

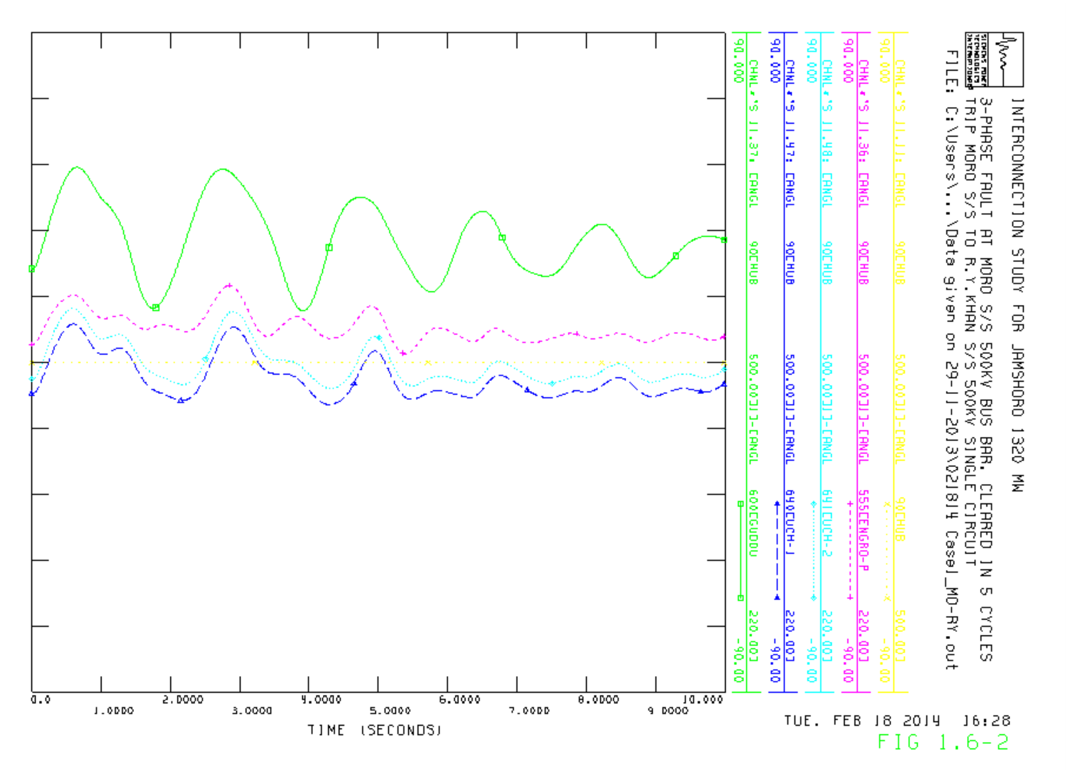




Case 1 (Thar Case, AAAC) Fault Section: Dadu S/S – Moro S/S

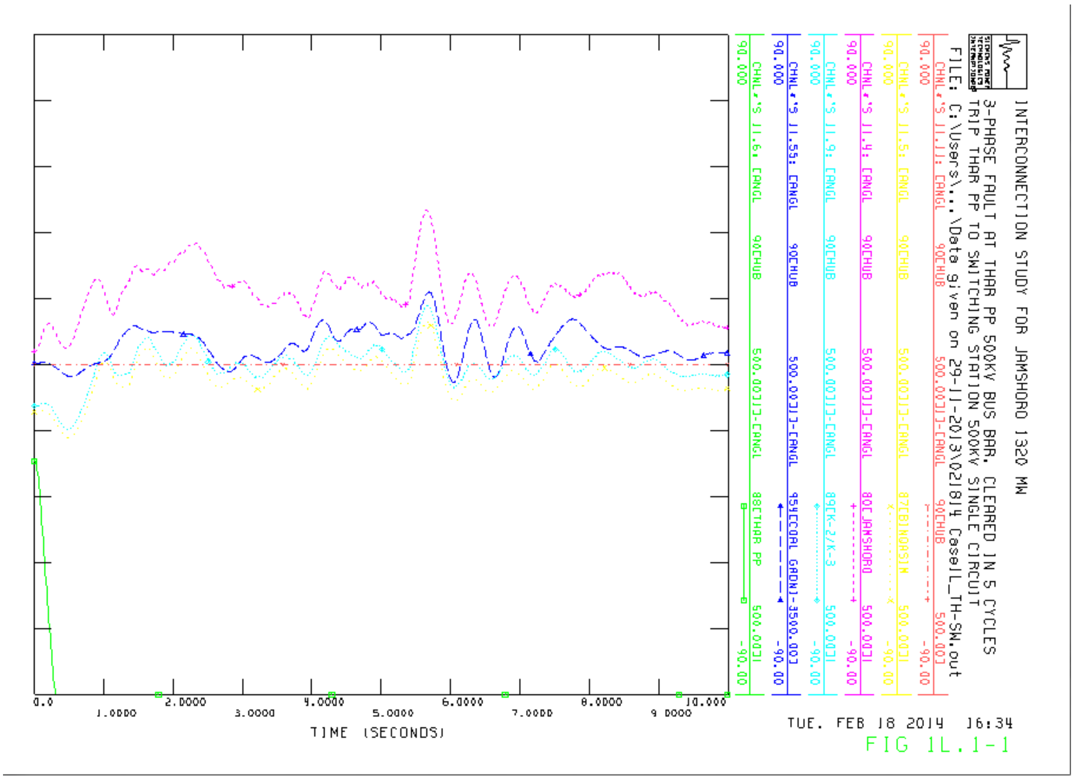
Transient Stability Analysis

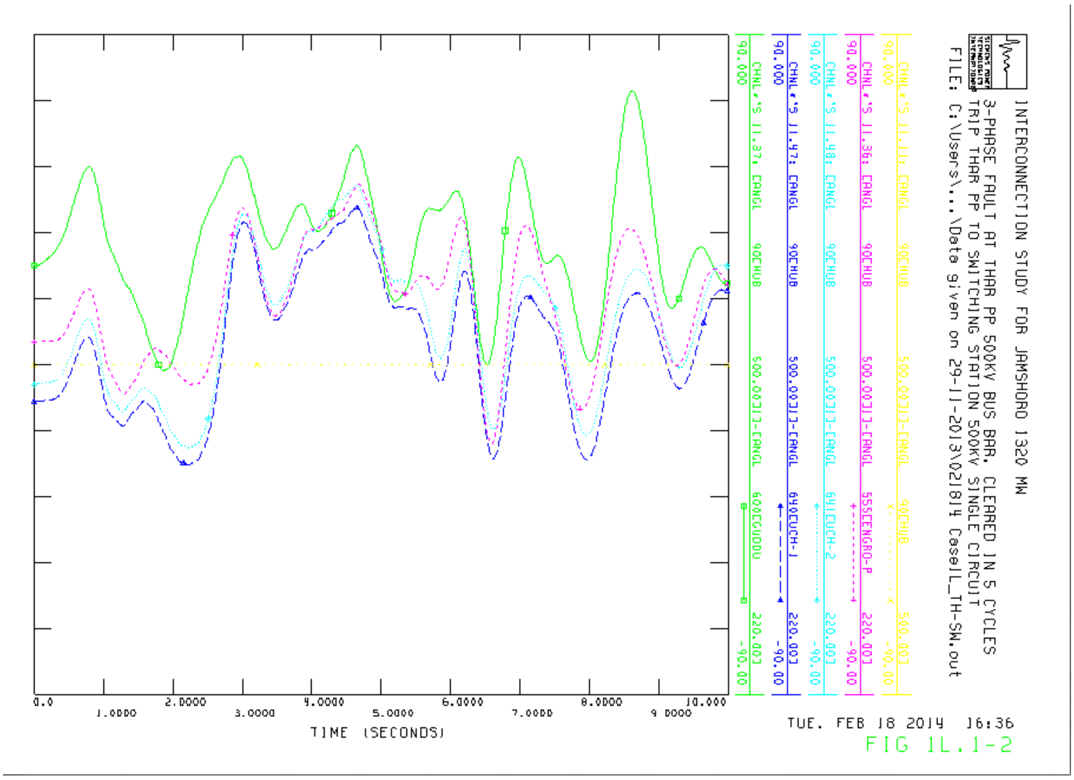




Case 1 (Thar Case, AAAC) Fault Section: Moro S/S – R. Y. Khan S/S

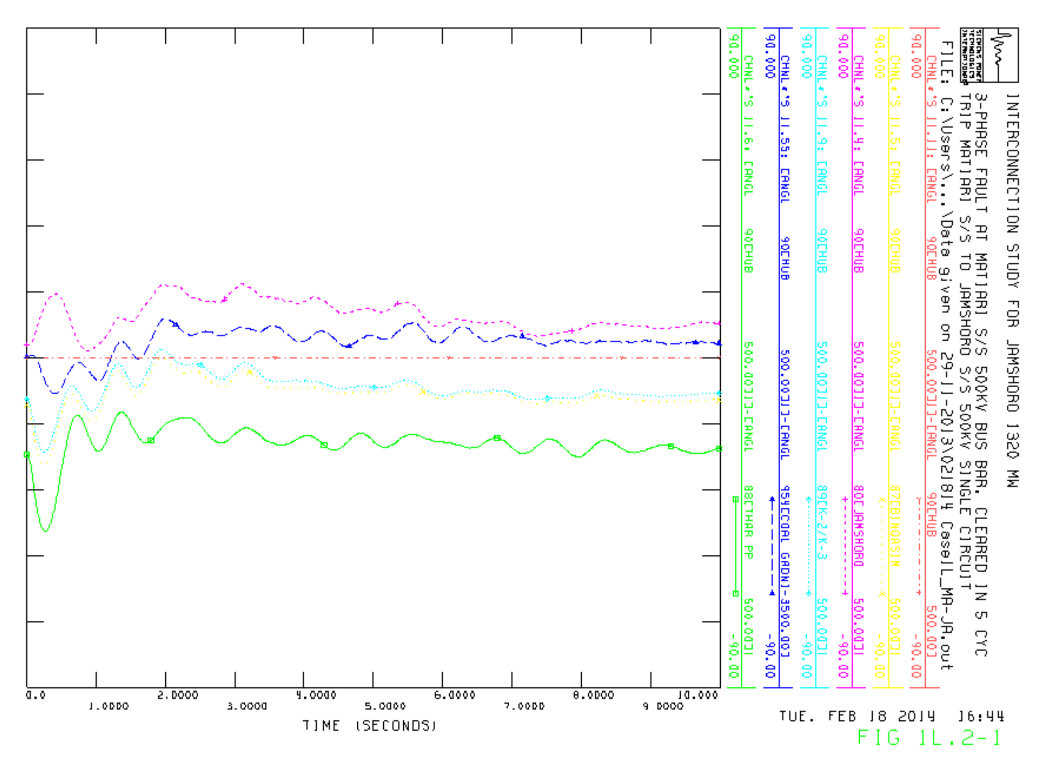
Transient Stability Analysis

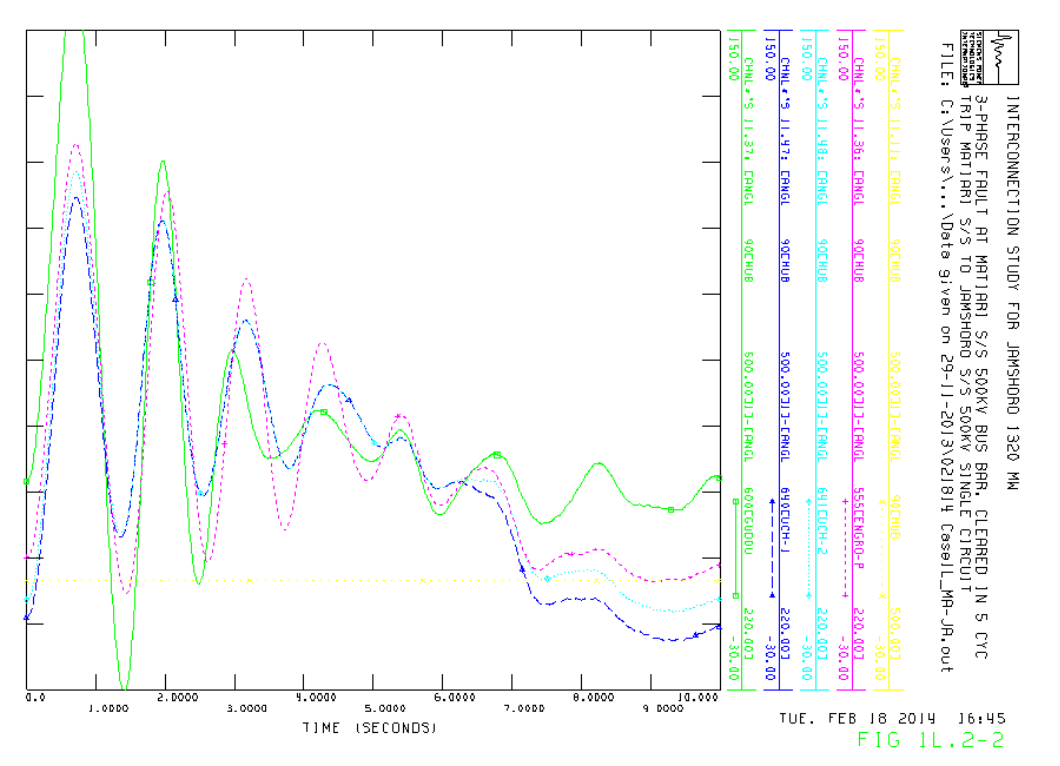




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Thar CFPP – Intermediate Switching Station

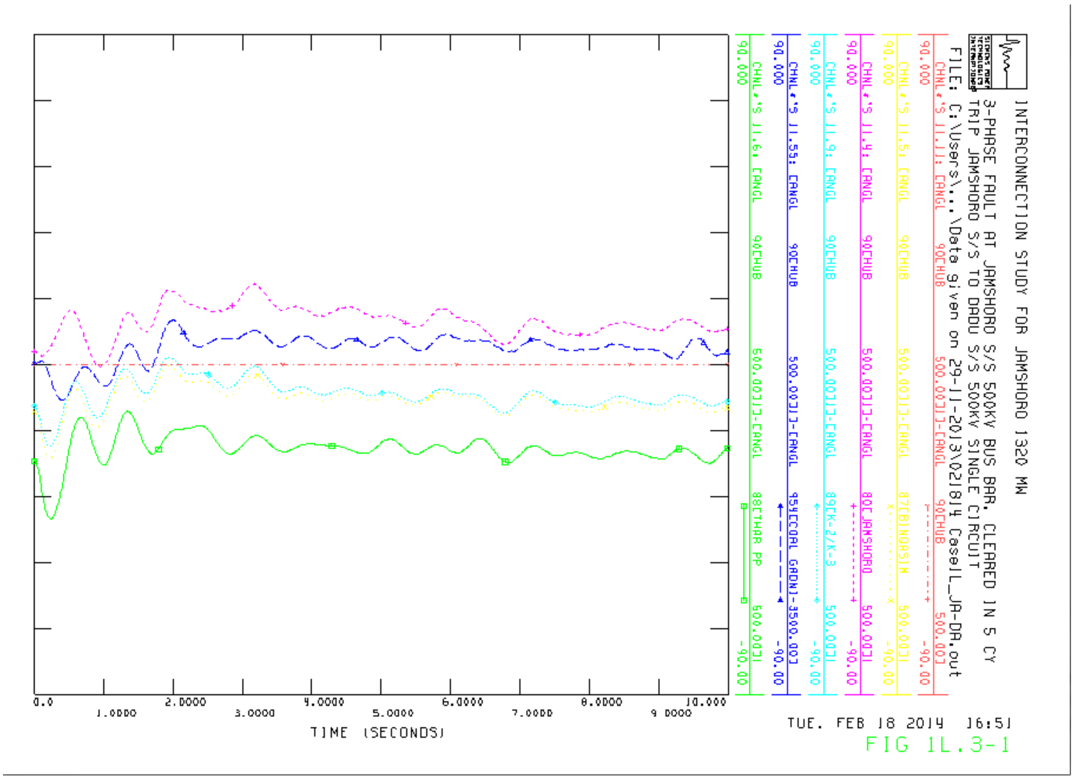
Transient Stability Analysis

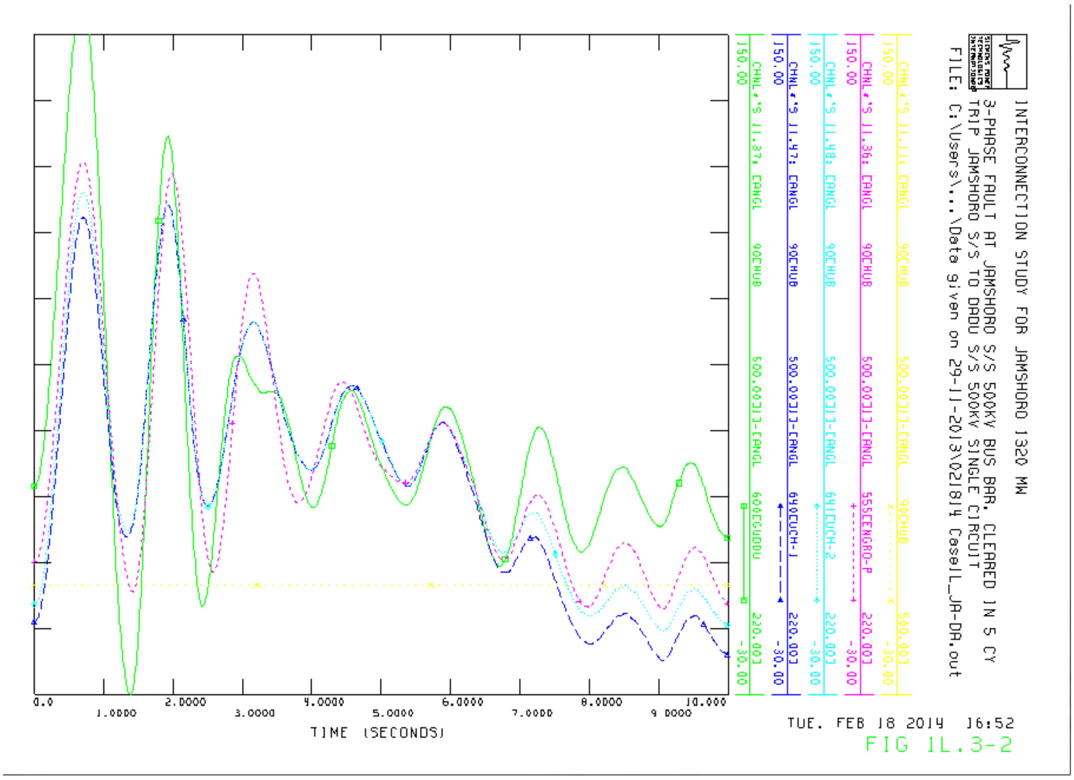




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Matiari S/S – Jamshoro S/S

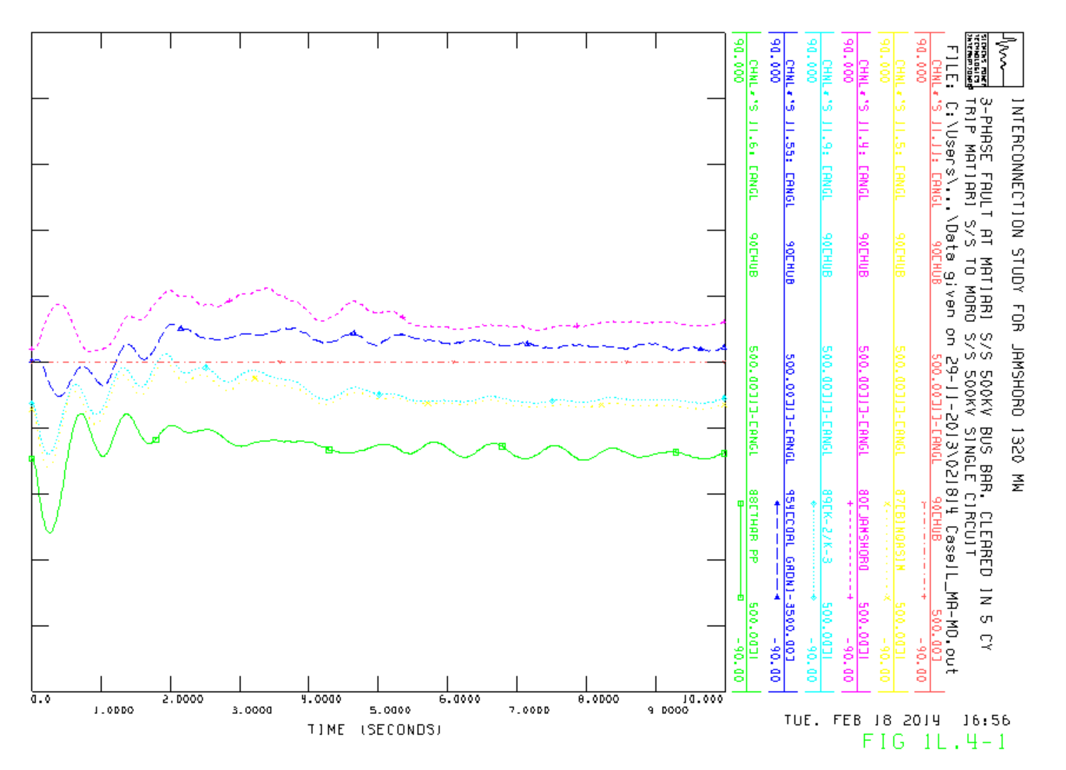
Transient Stability Analysis

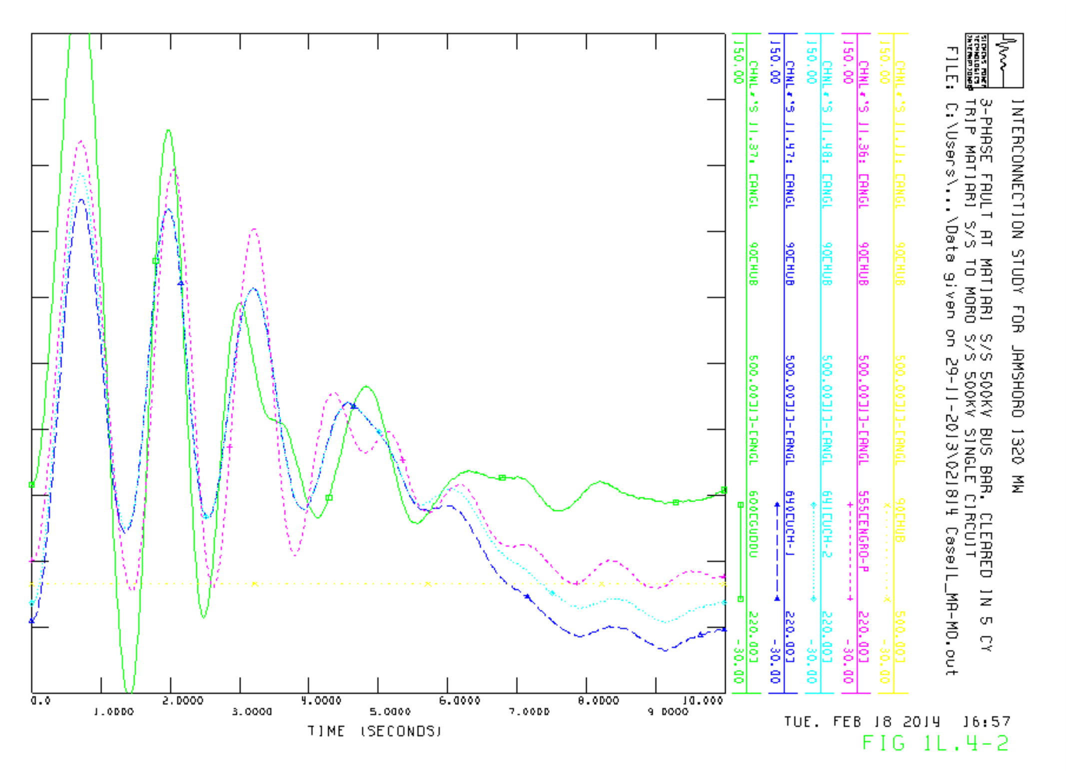




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Jamshoro S/S – Dadu S/S

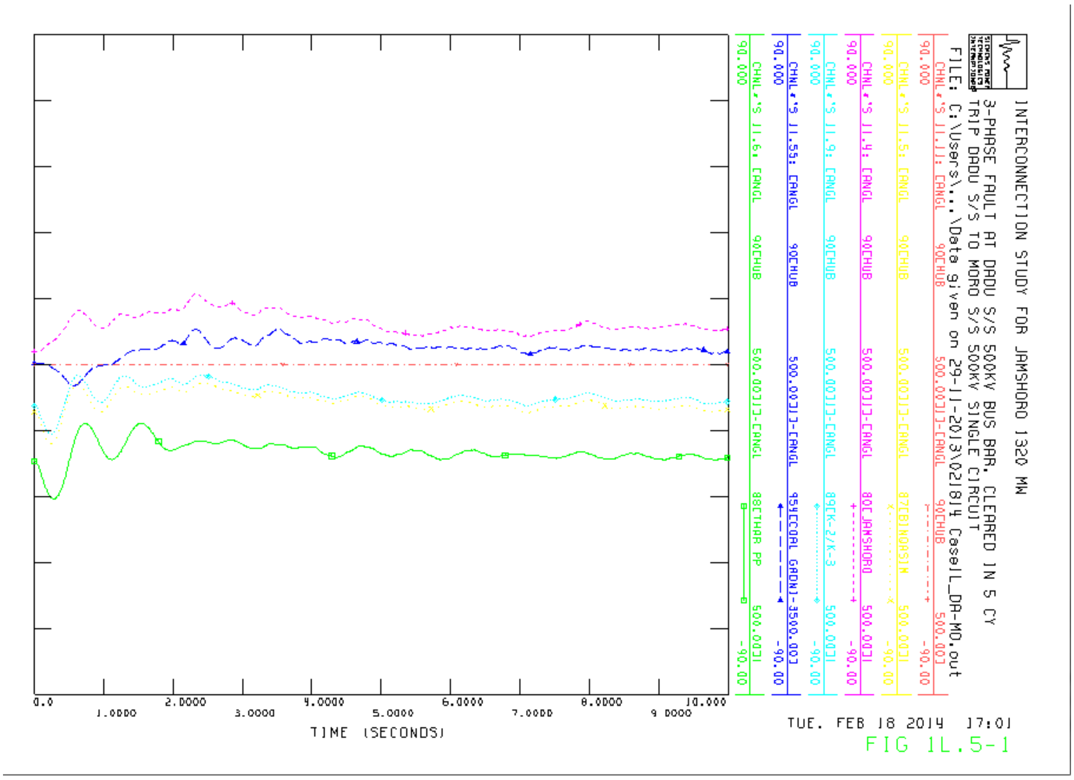
Transient Stability Analysis

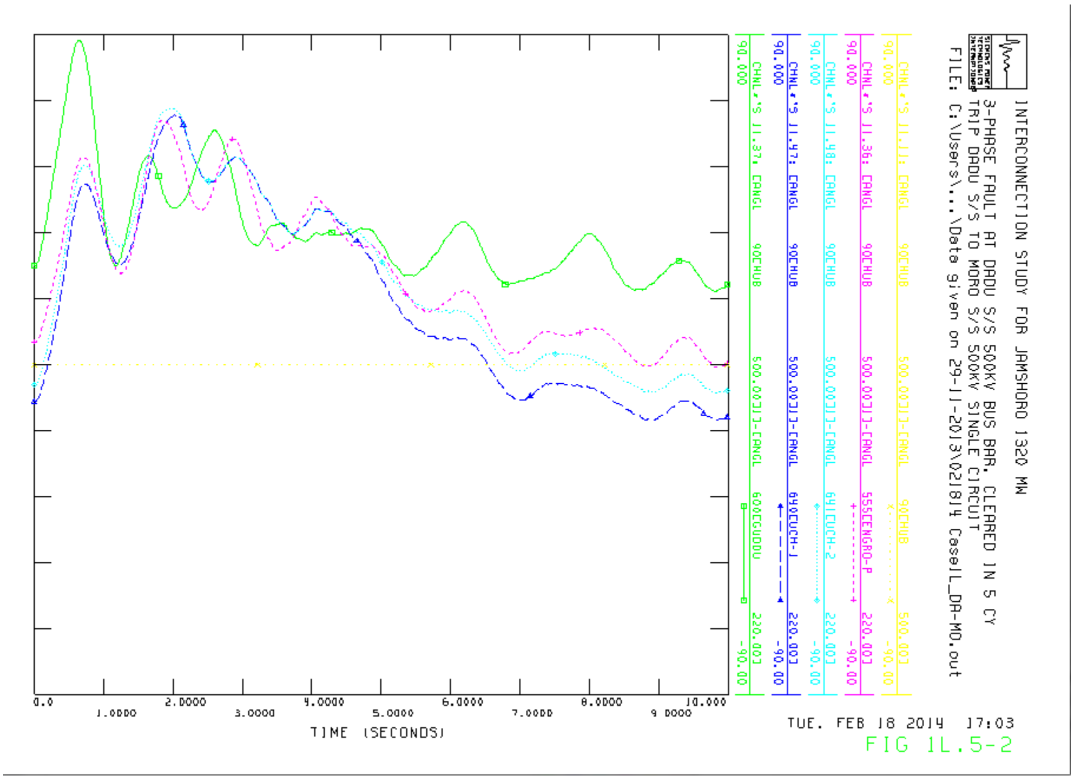




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Matiari S/S – Moro S/S

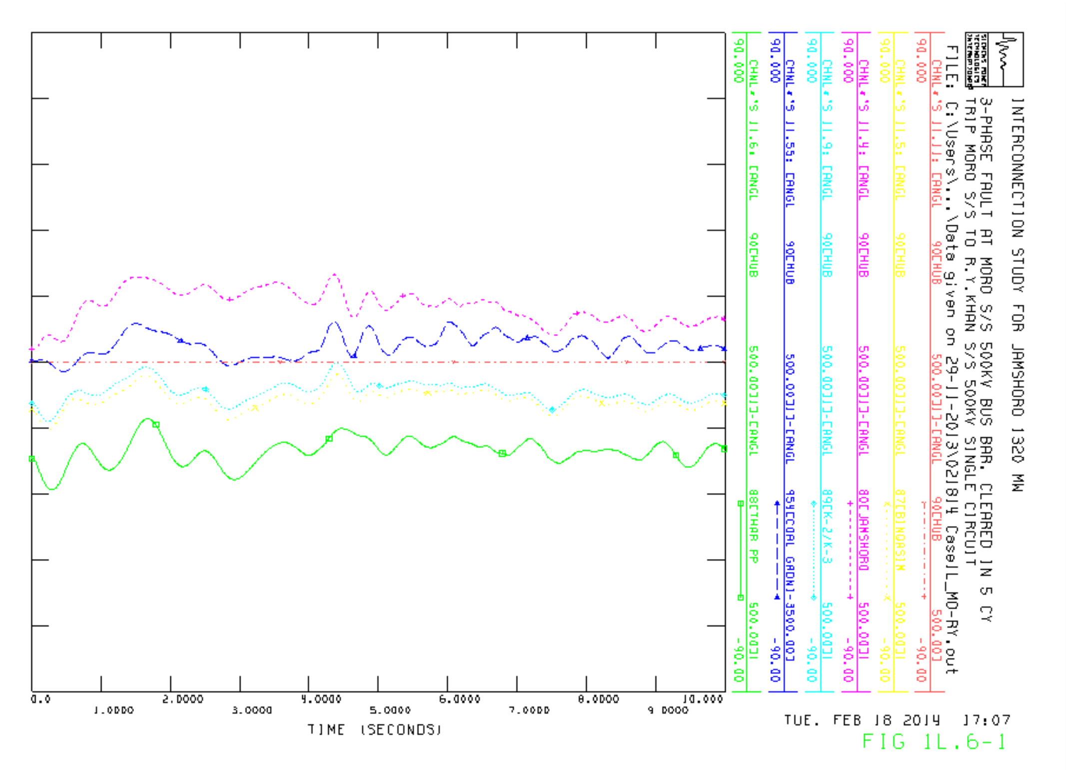
Transient Stability Analysis

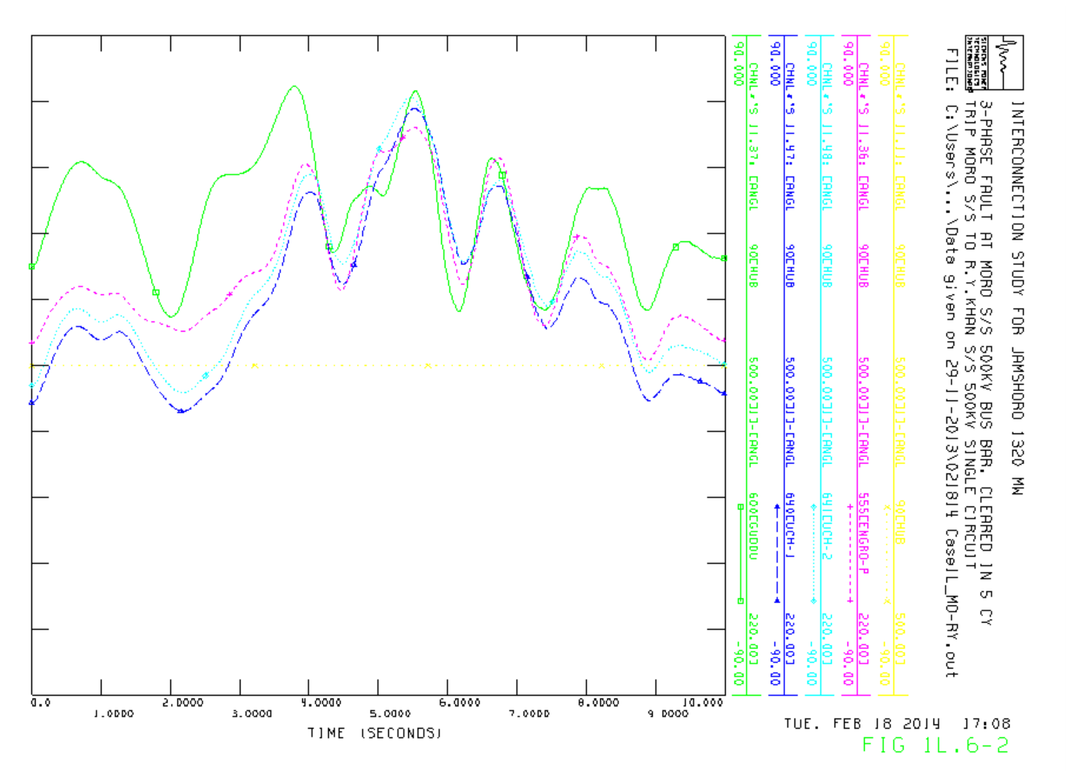




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Dadu S/S – Moro S/S

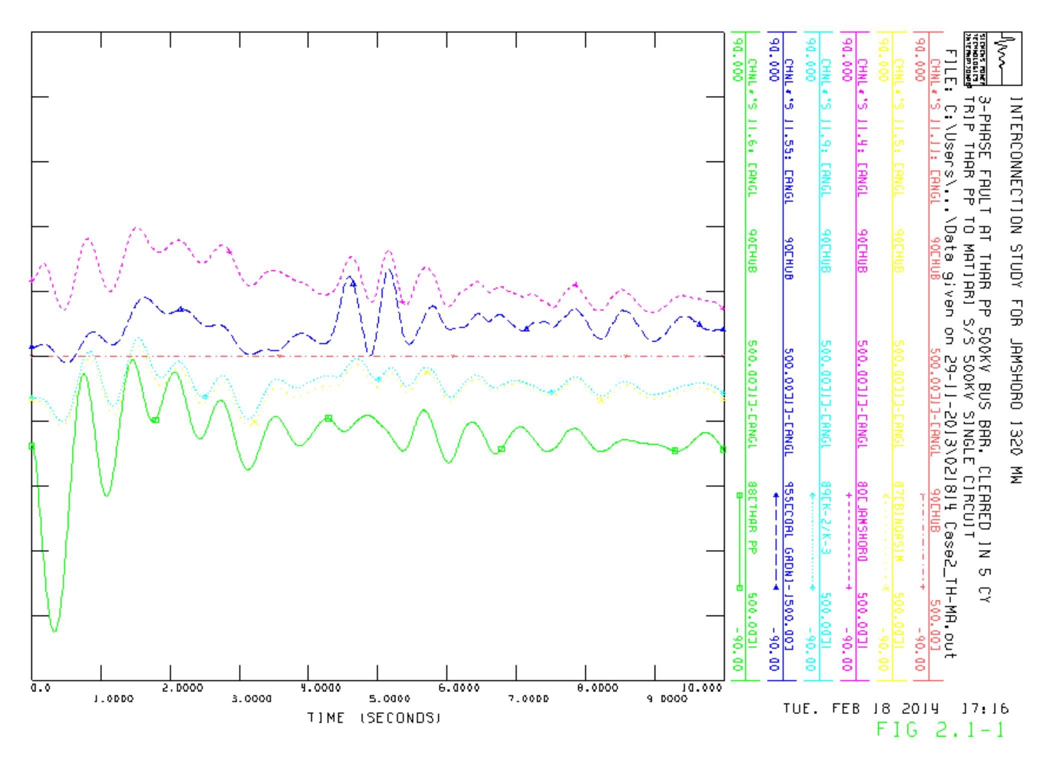
Transient Stability Analysis

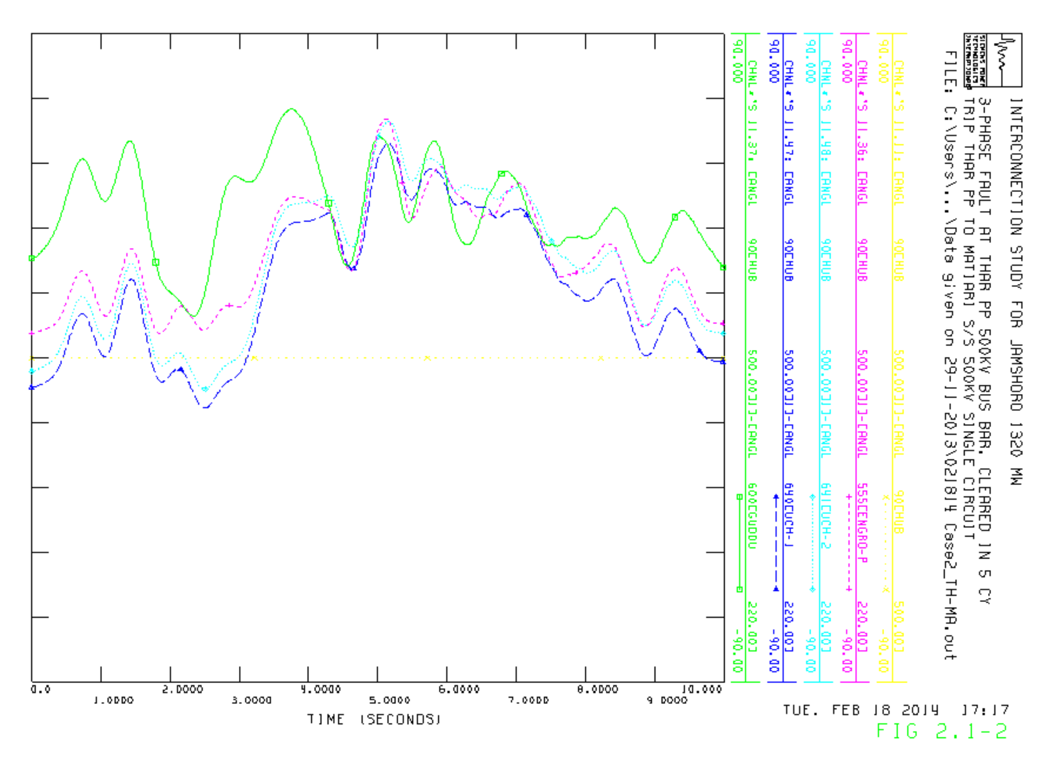




Case 1L (Thar Case, LL-TACSR/AC + Intermediate Switching Station)
Fault Section: Moro S/S – R. Y. Khan S/S

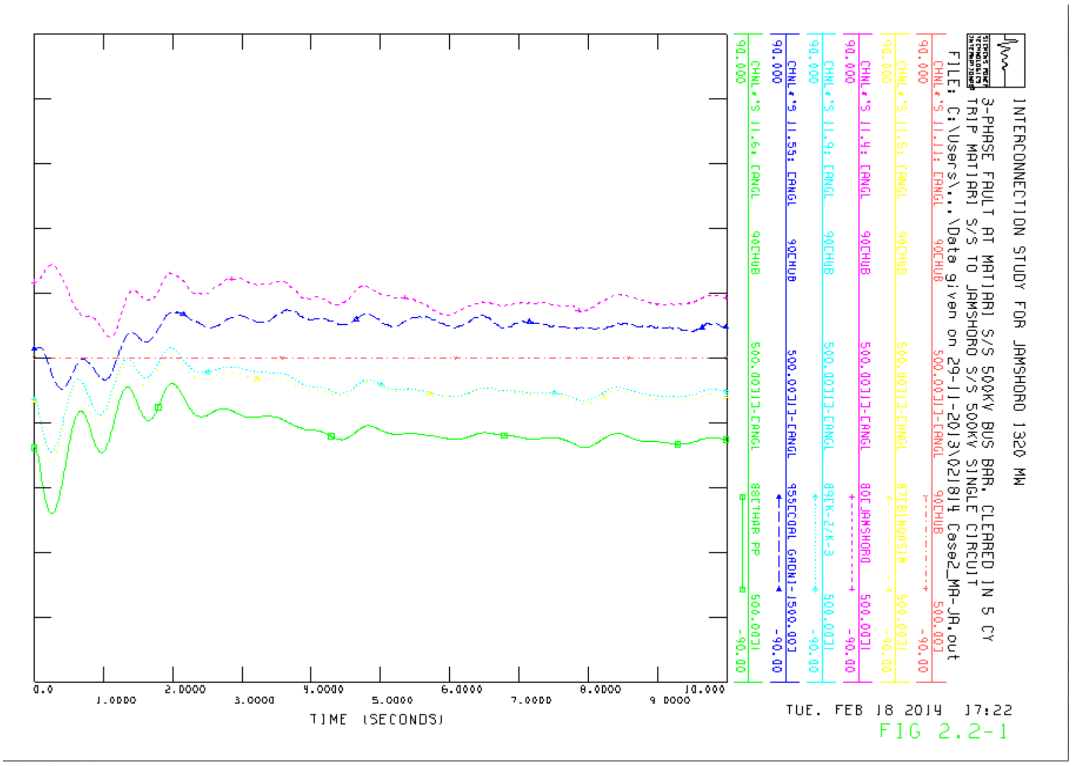
Transient Stability Analysis

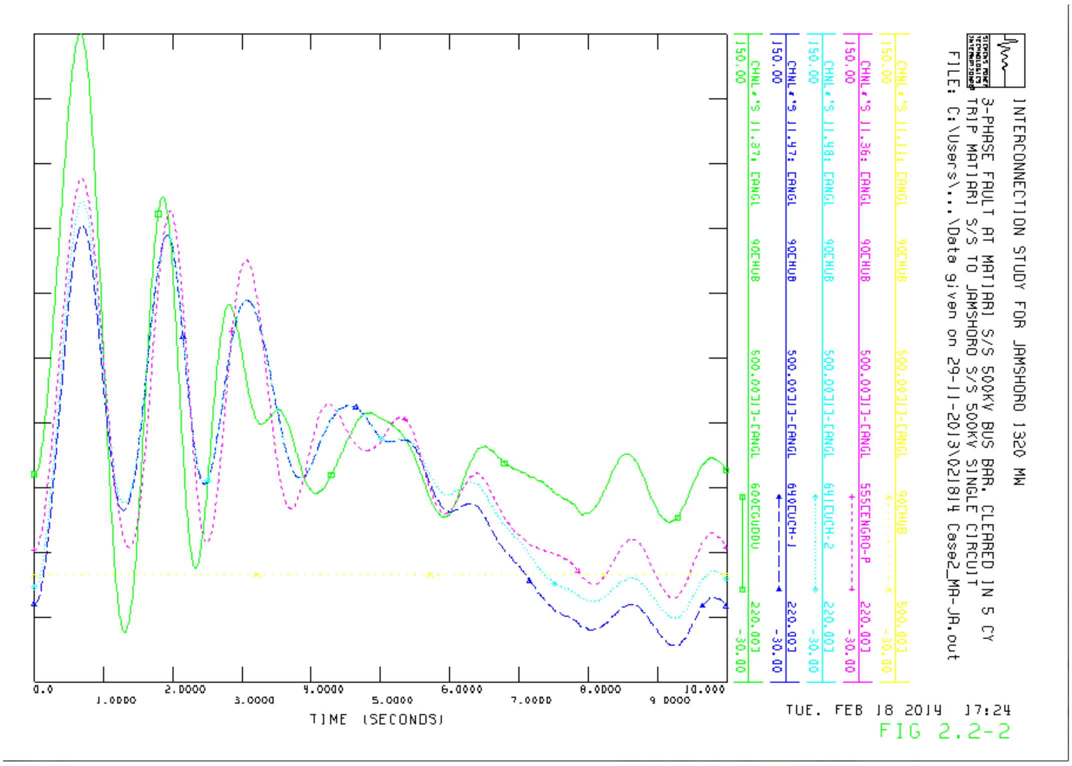




Case 2 (Lakhra Case), Fault Section: Thar CFPP – Matiari S/S

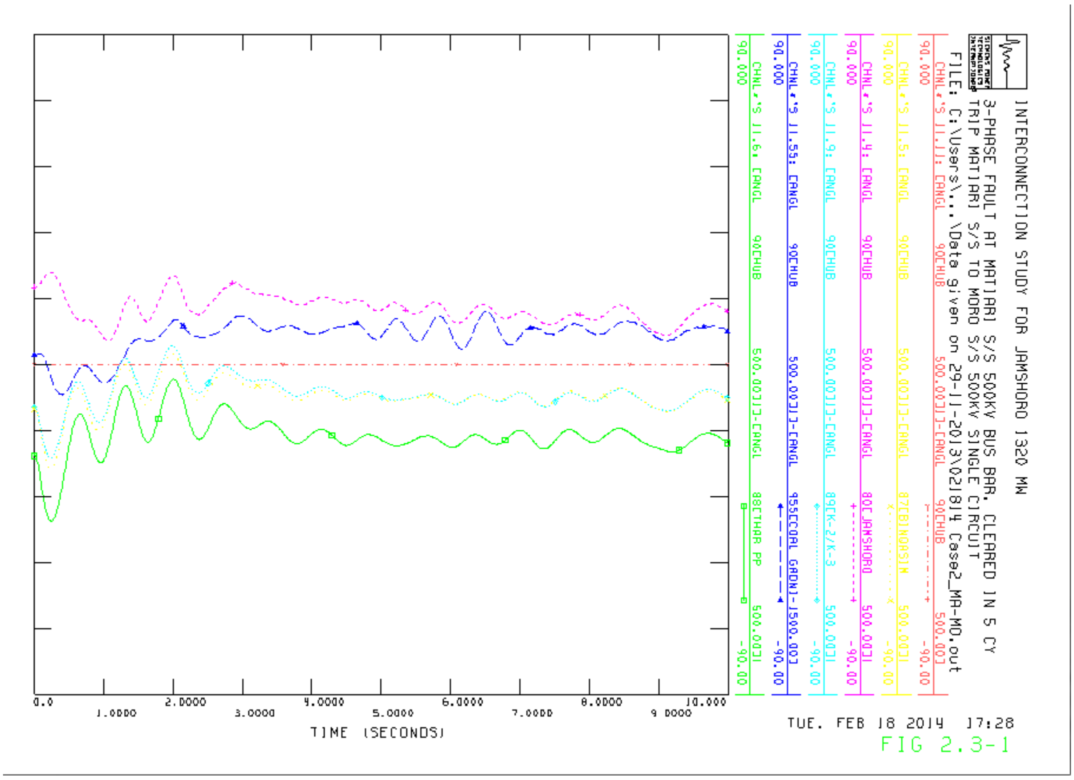
Transient Stability Analysis

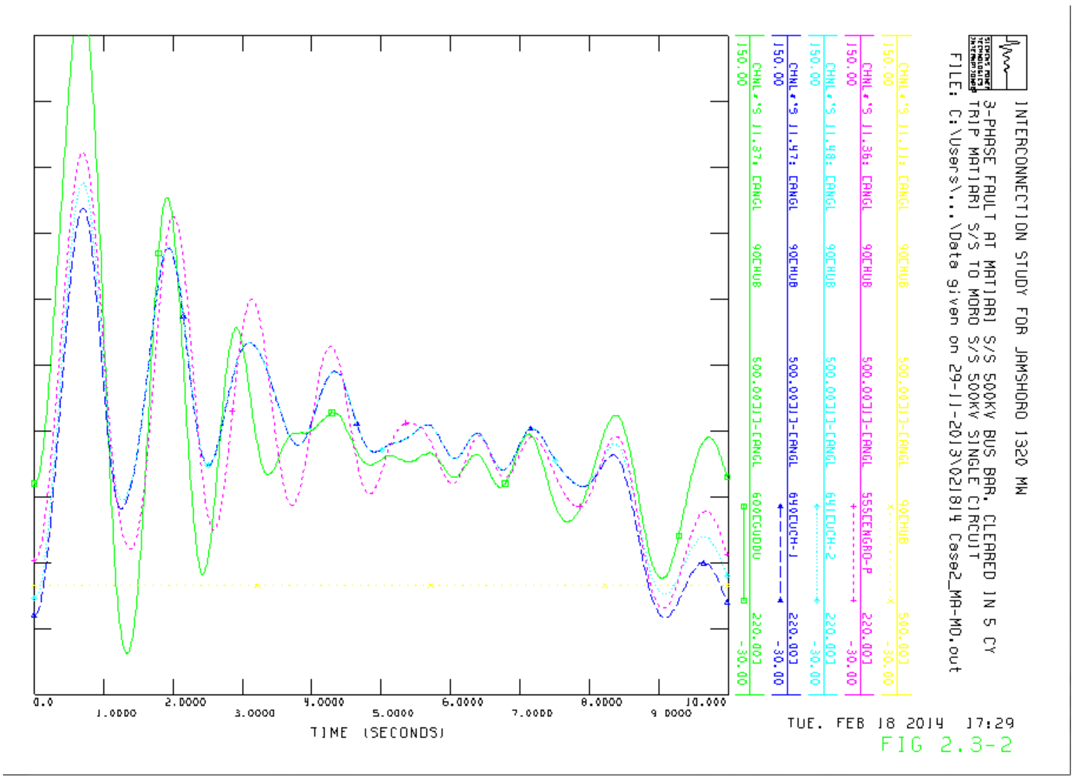




Case 2 (Lakhra Case), Fault Section: Matiari S/S – Jamshoro S/S

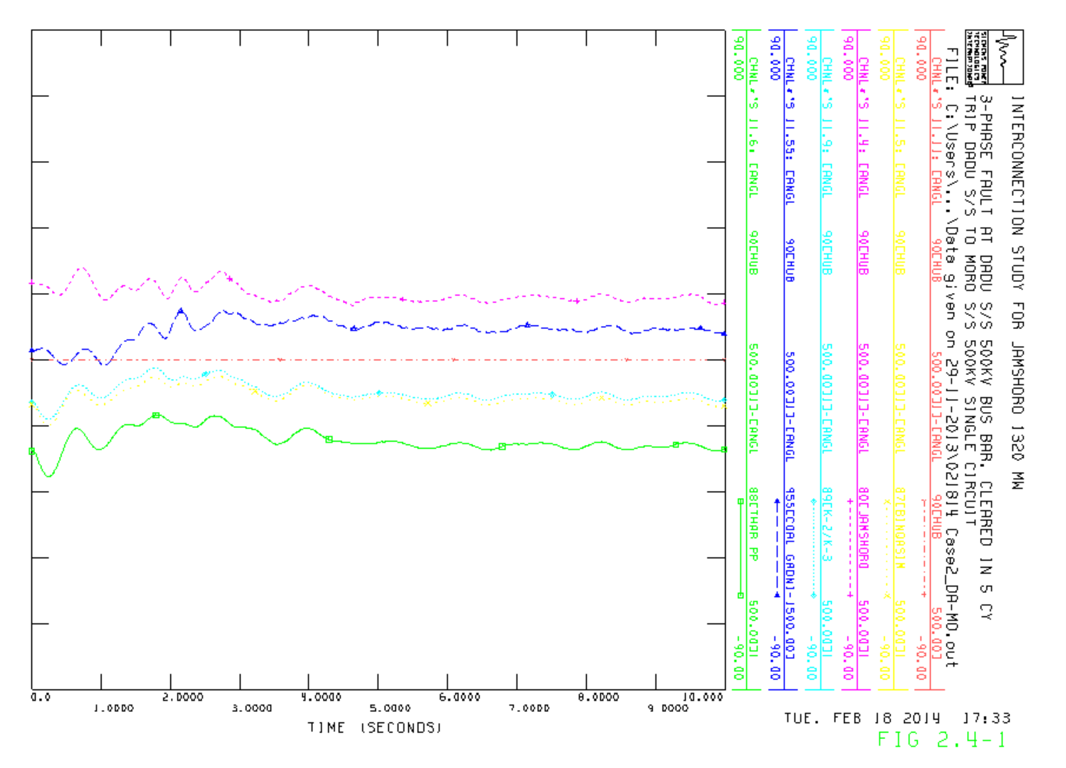
Transient Stability Analysis

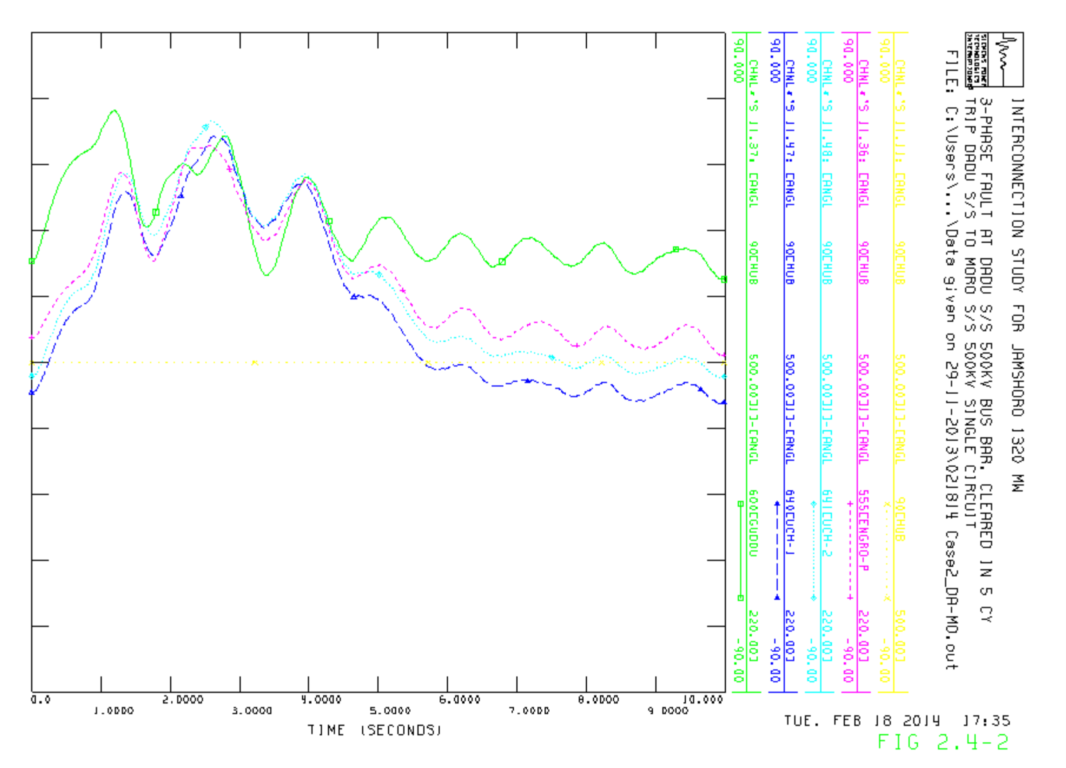




Case 2 (Lakhra Case), Fault Section: Matiari S/S – Moro S/S

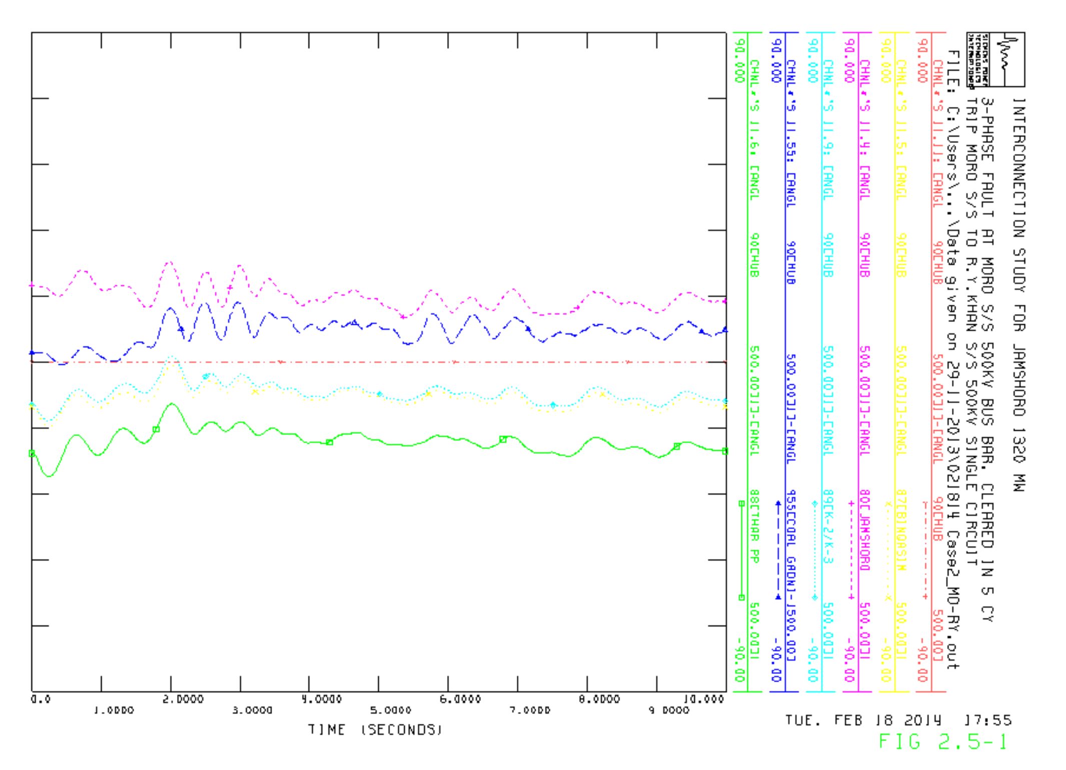
Transient Stability Analysis

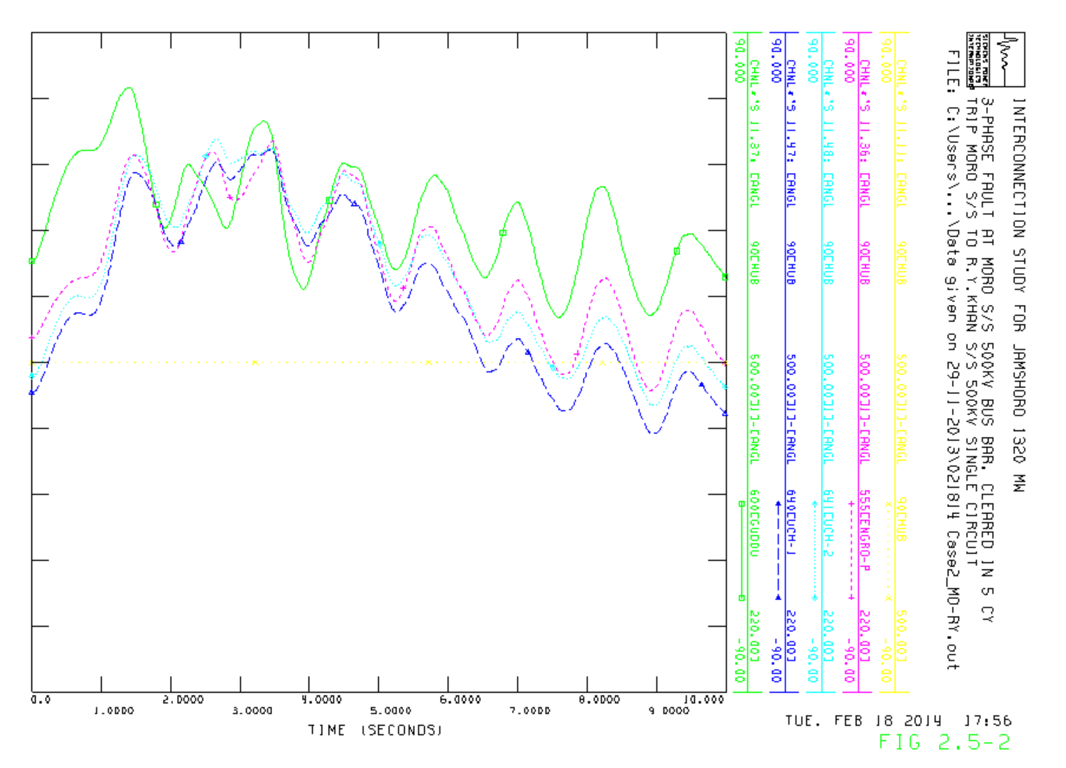




Case 2 (Lakhra Case), Fault Section: Dadu S/S – Moro S/S

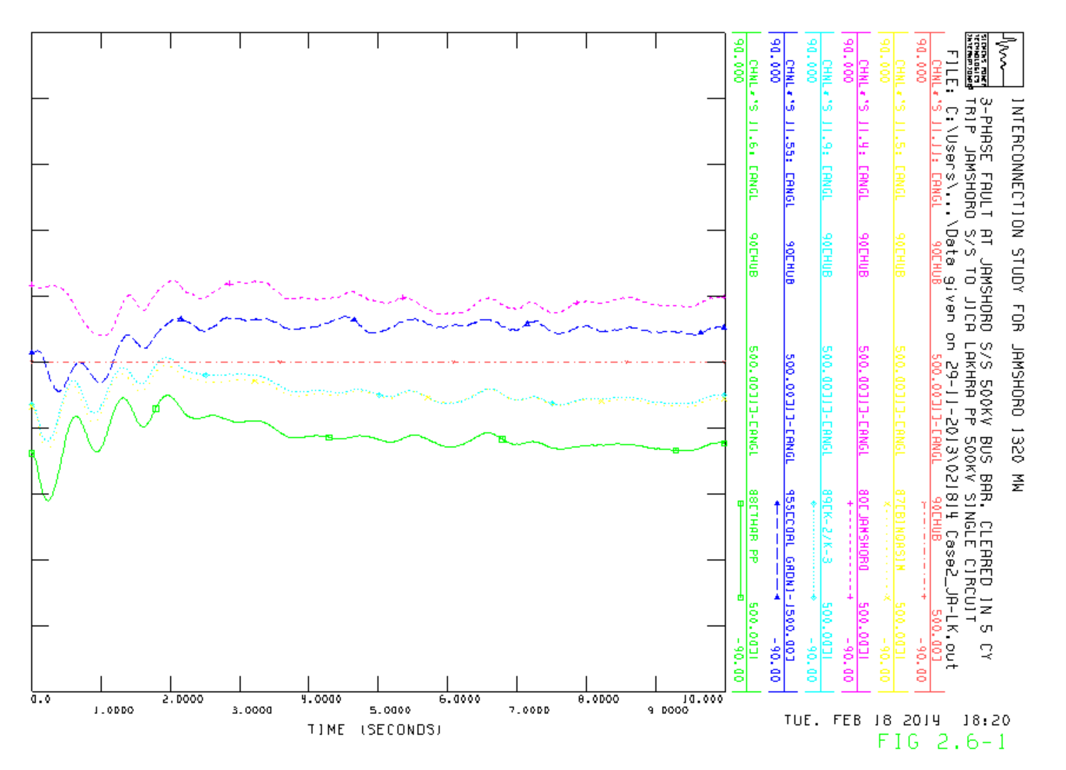
Transient Stability Analysis

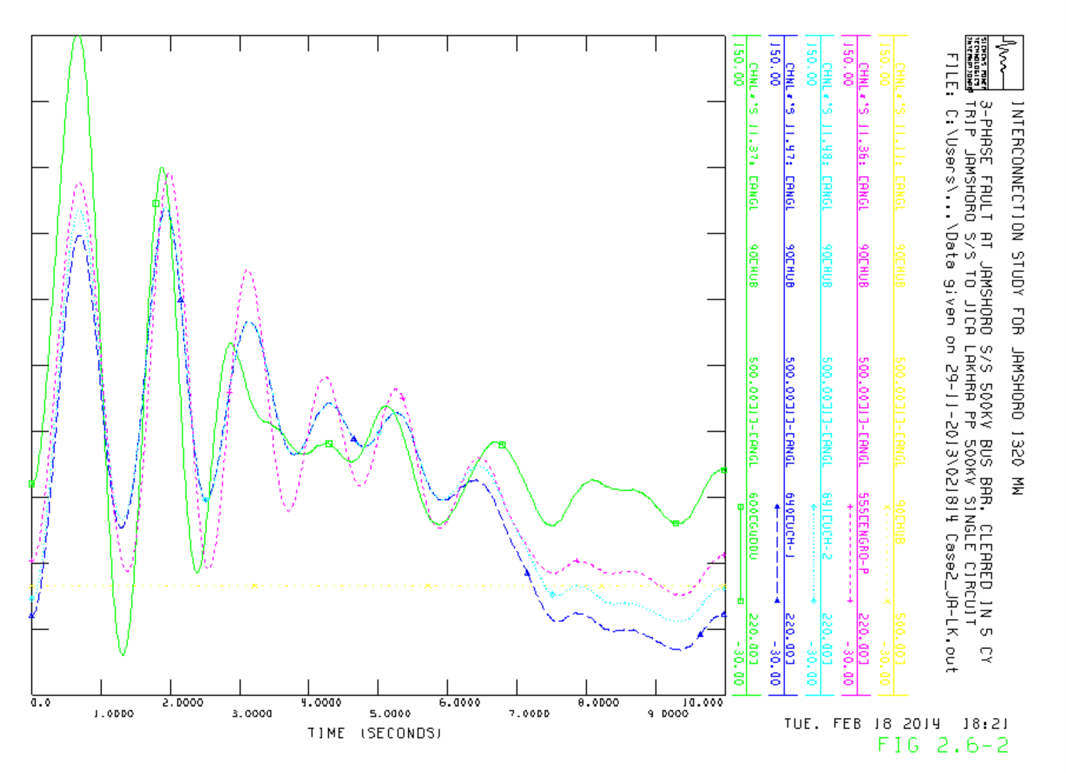




Case 2 (Lakhra Case), Fault Section: Moro S/S – R. Y. Khan S/S

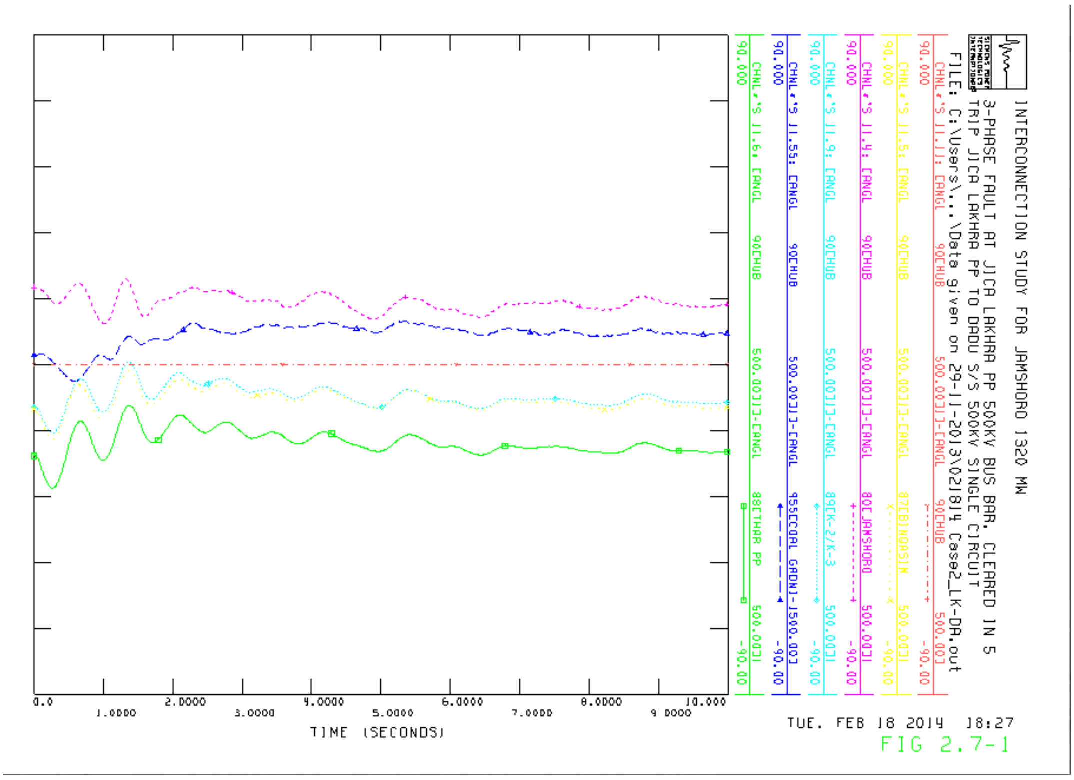
Transient Stability Analysis

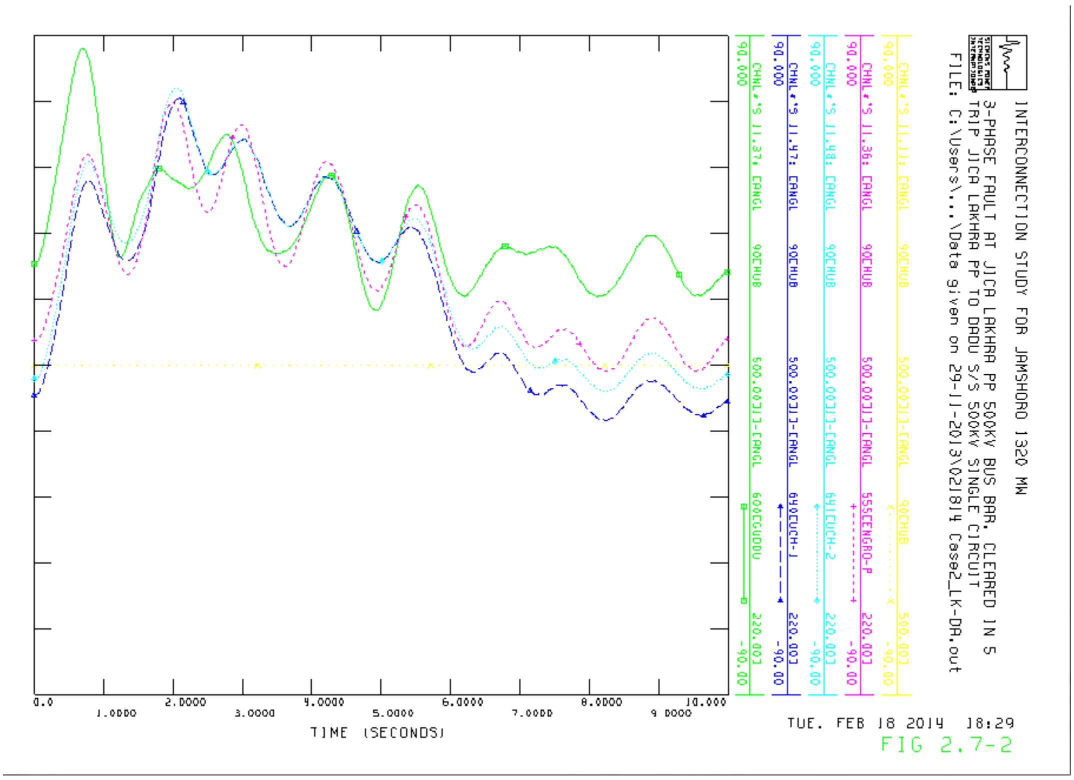




Case 2 (Lakhra Case), Fault Section: Jamshoro S/S – JICA Lakhra CFPP

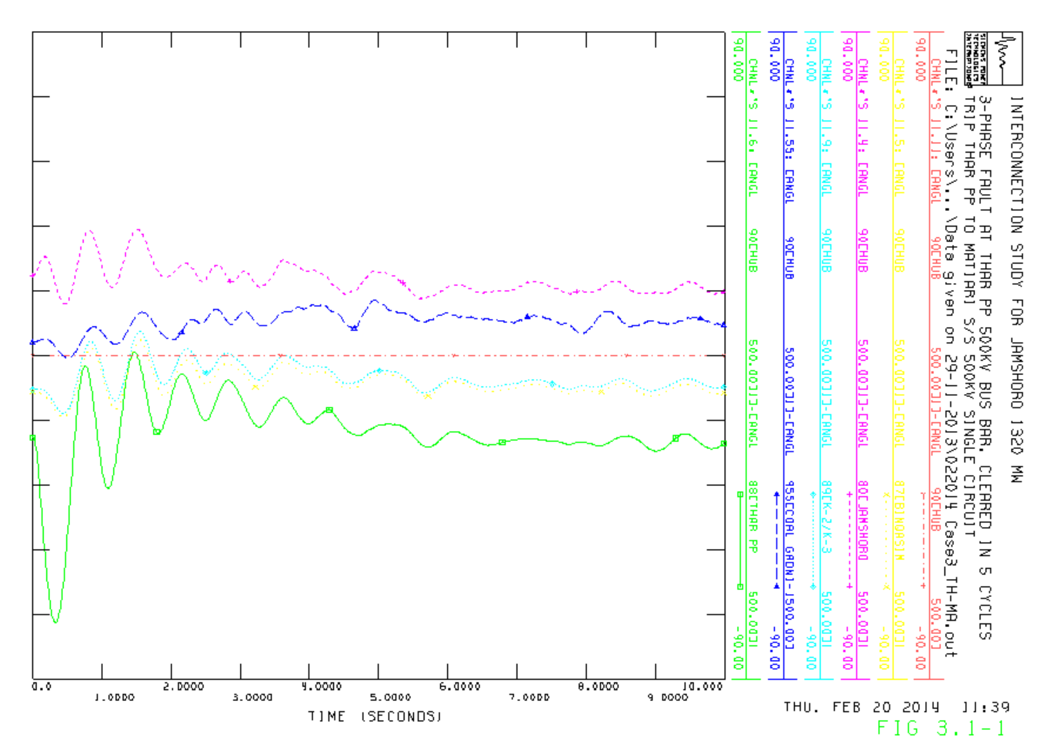
Transient Stability Analysis

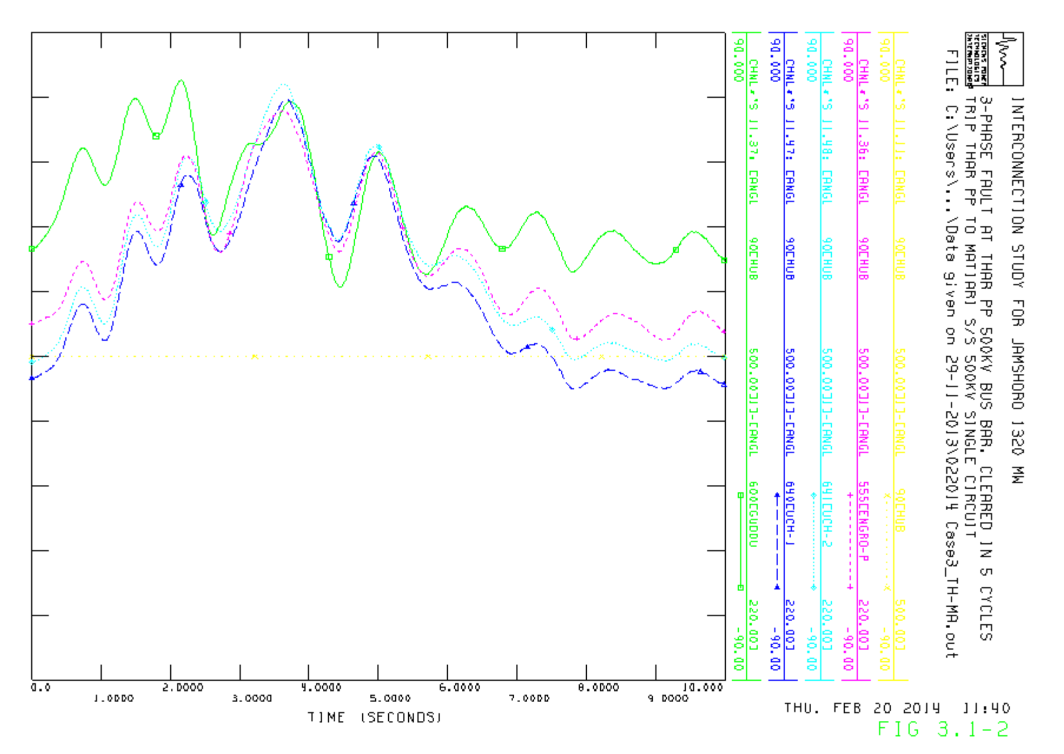




Case 2 (Lakhra Case), Fault Section: JICA Lakhra CFPP – Dadu S/S

Transient Stability Analysis





Case 3 (Qasim Case), Fault Section: Thar CFPP – Matiari S/S

Transient Stability Analysis

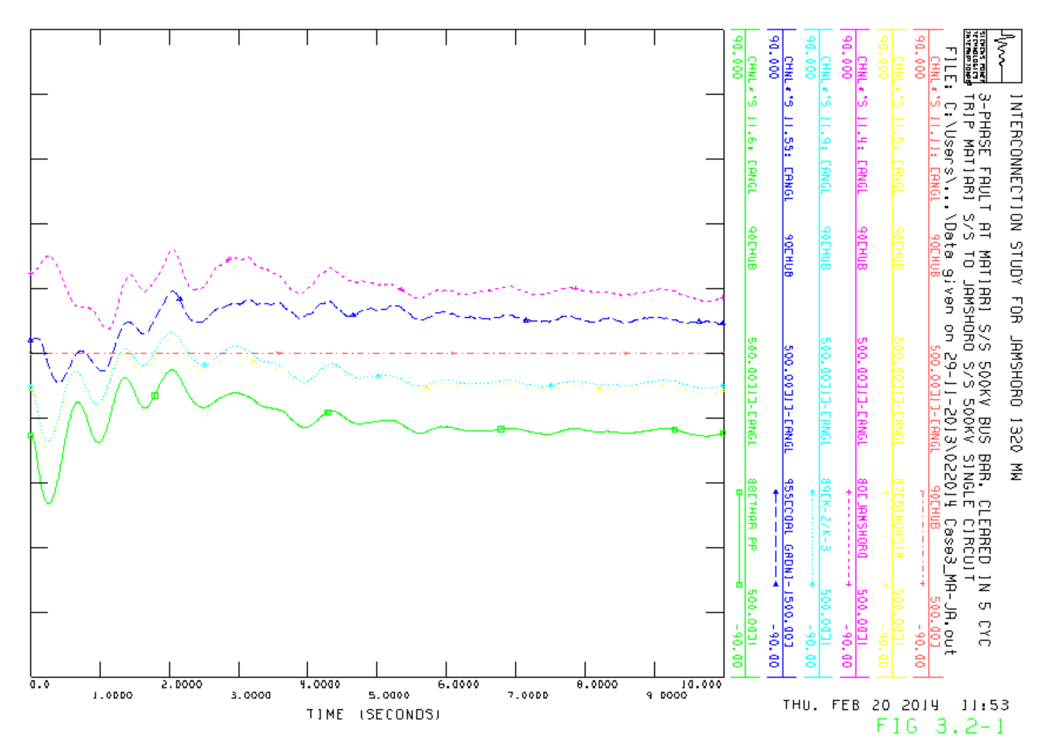


FIG 3.2-1

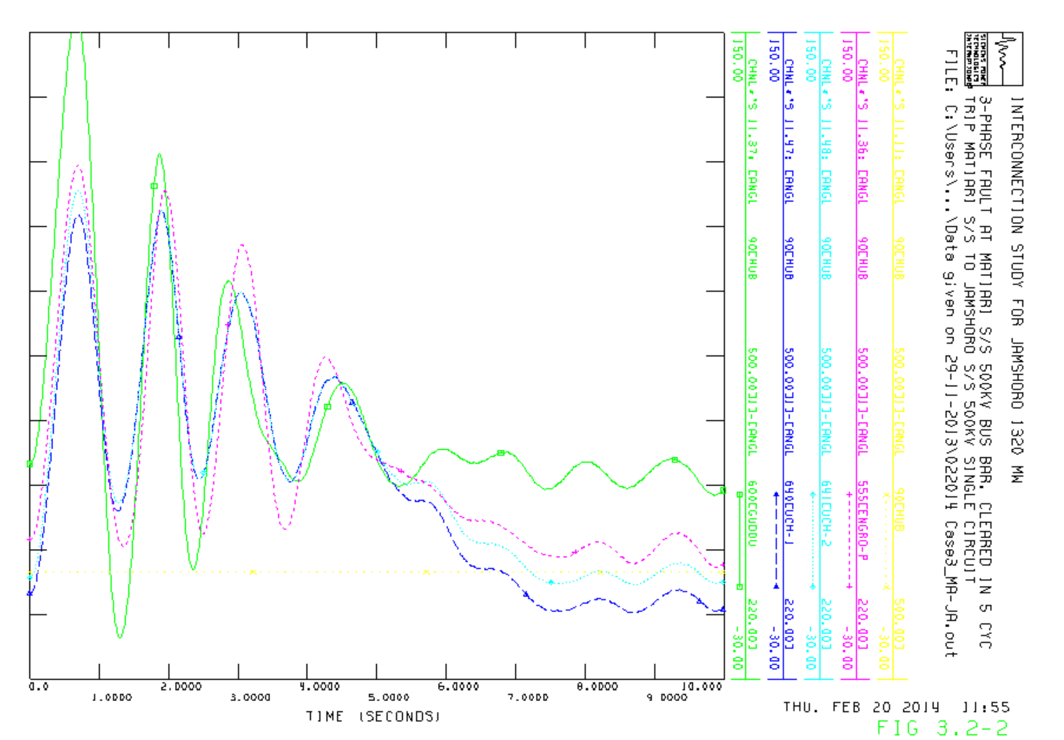
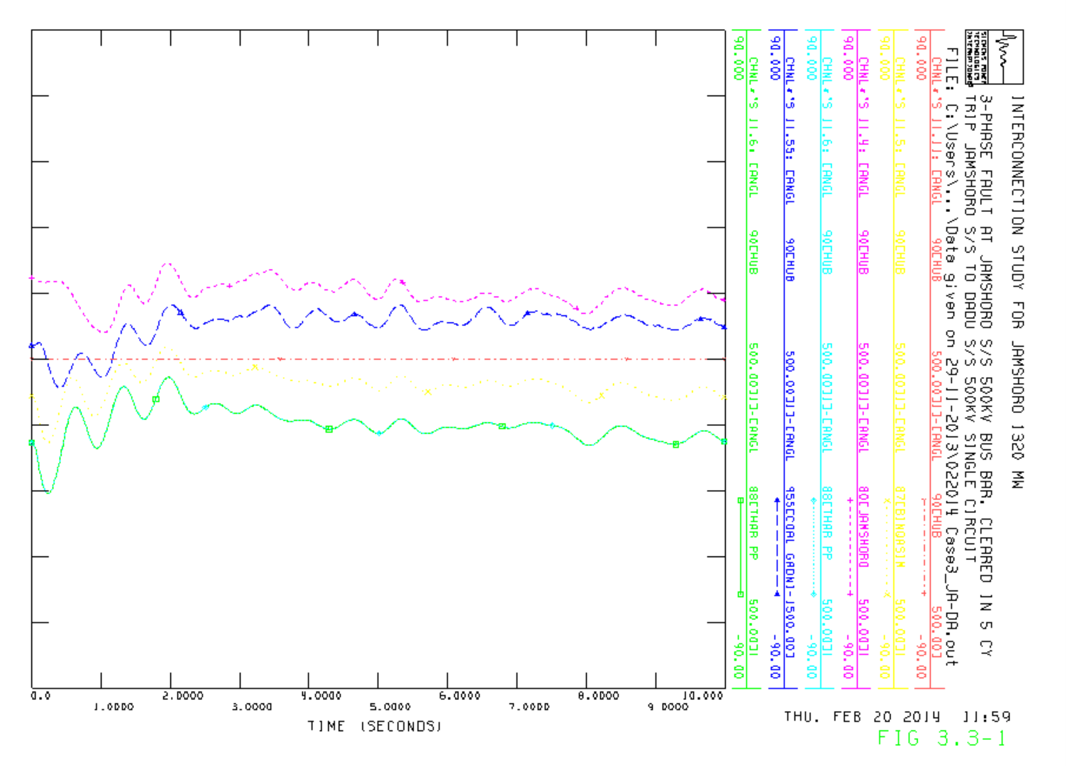
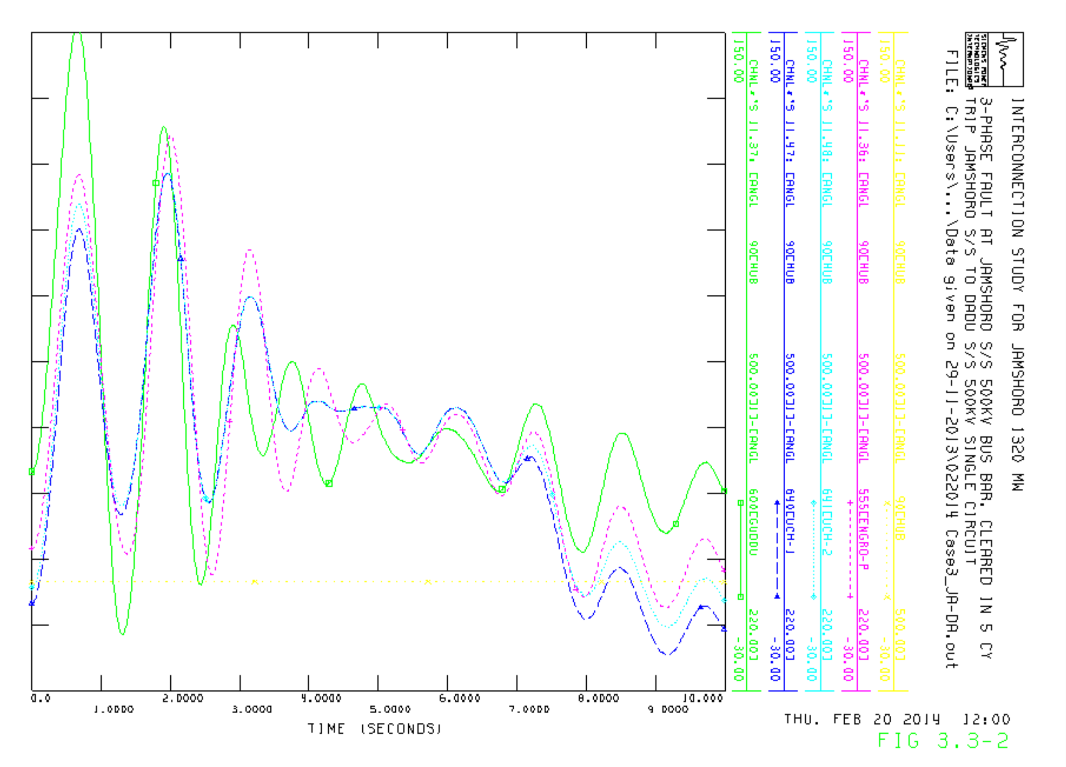


FIG 3.2-2

Case 3 (Qasim Case), Fault Section: Matiari S/S – Jamshoro S/S

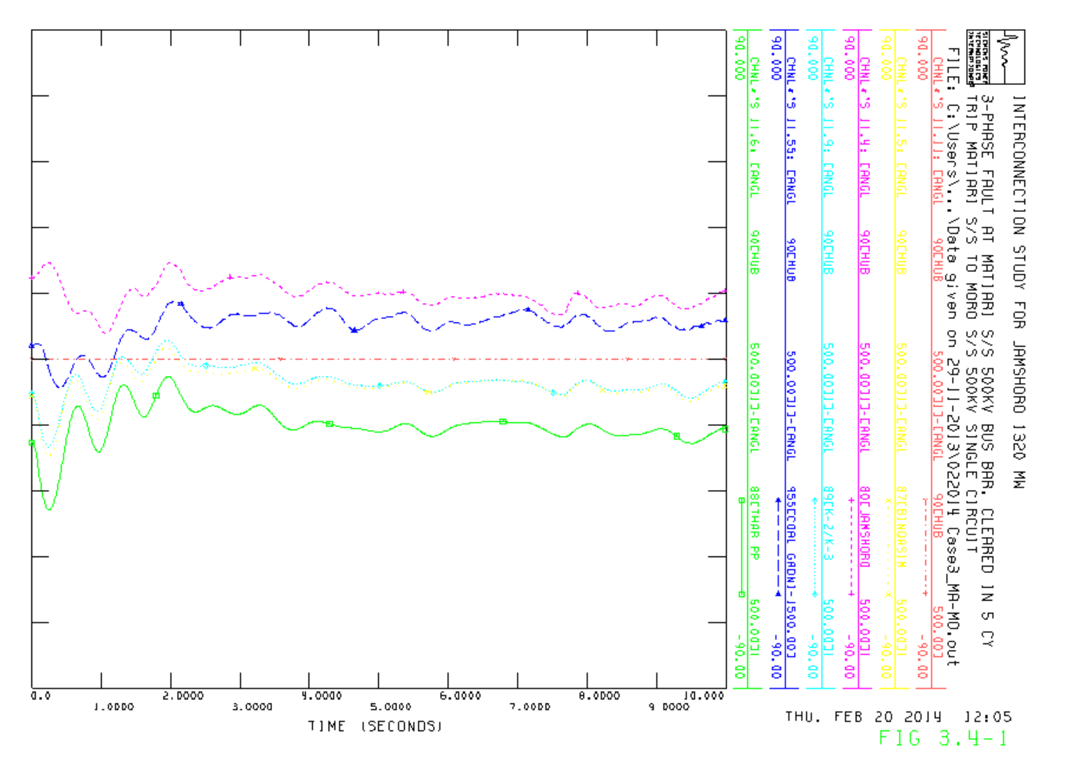
Transient Stability Analysis

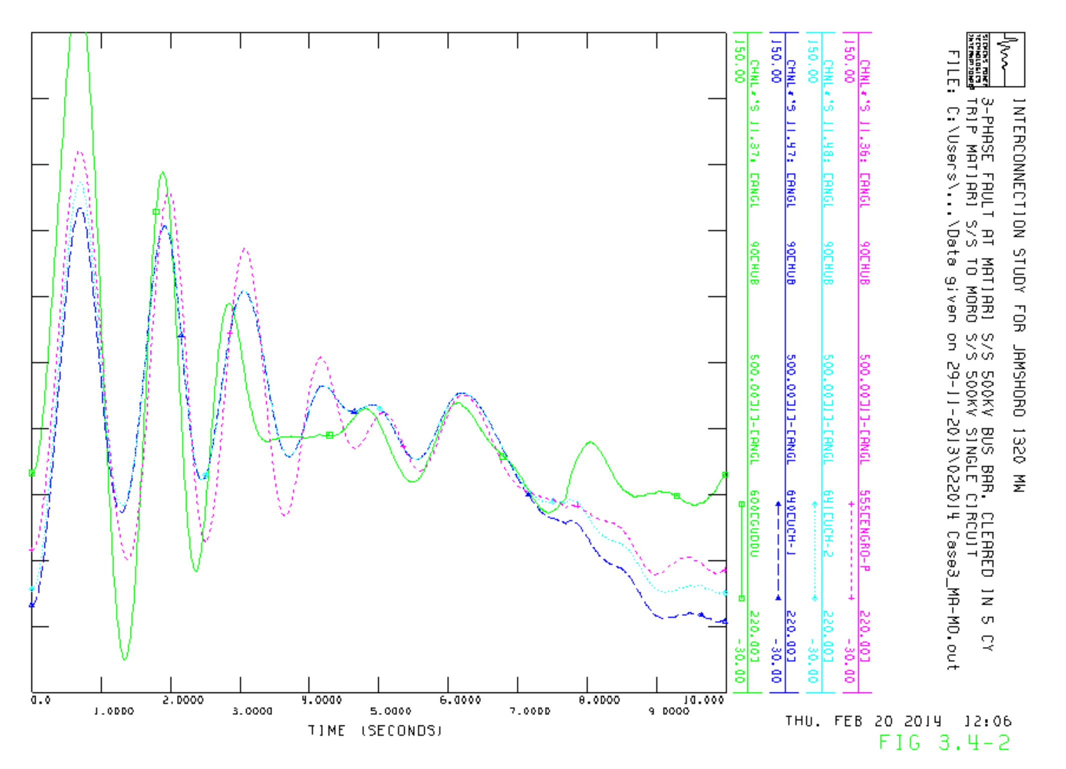




Case 3 (Qasim Case), Fault Section: Jamshoro S/S – Dadu S/S

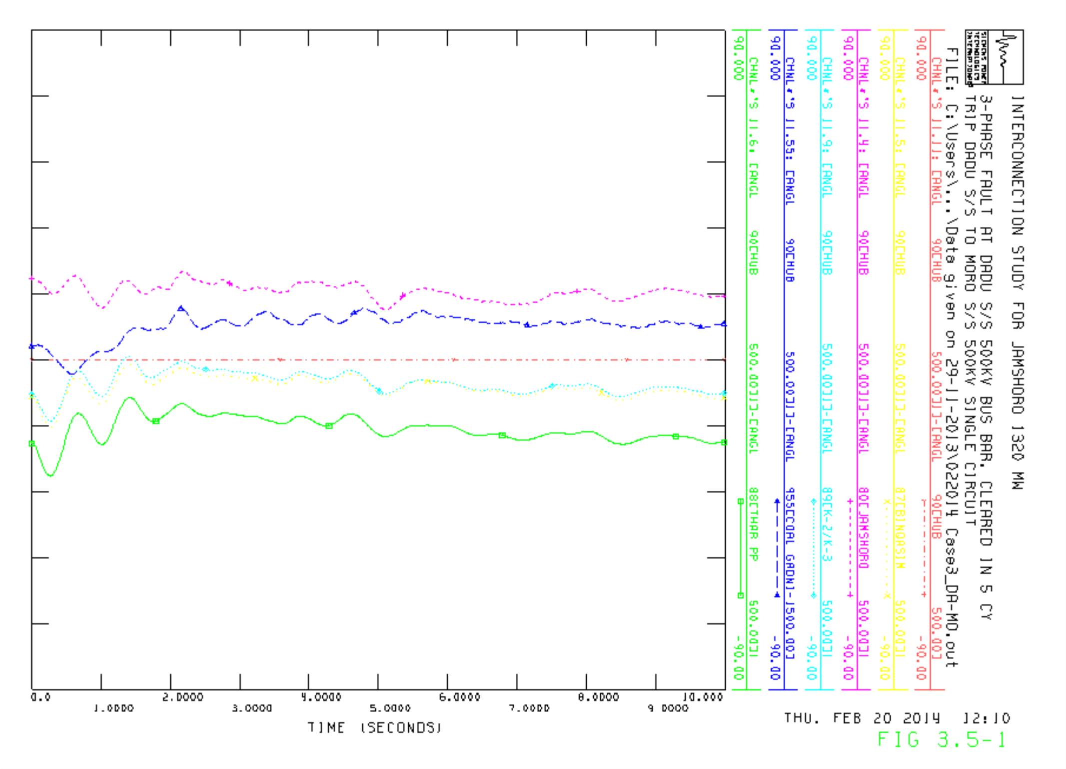
Transient Stability Analysis

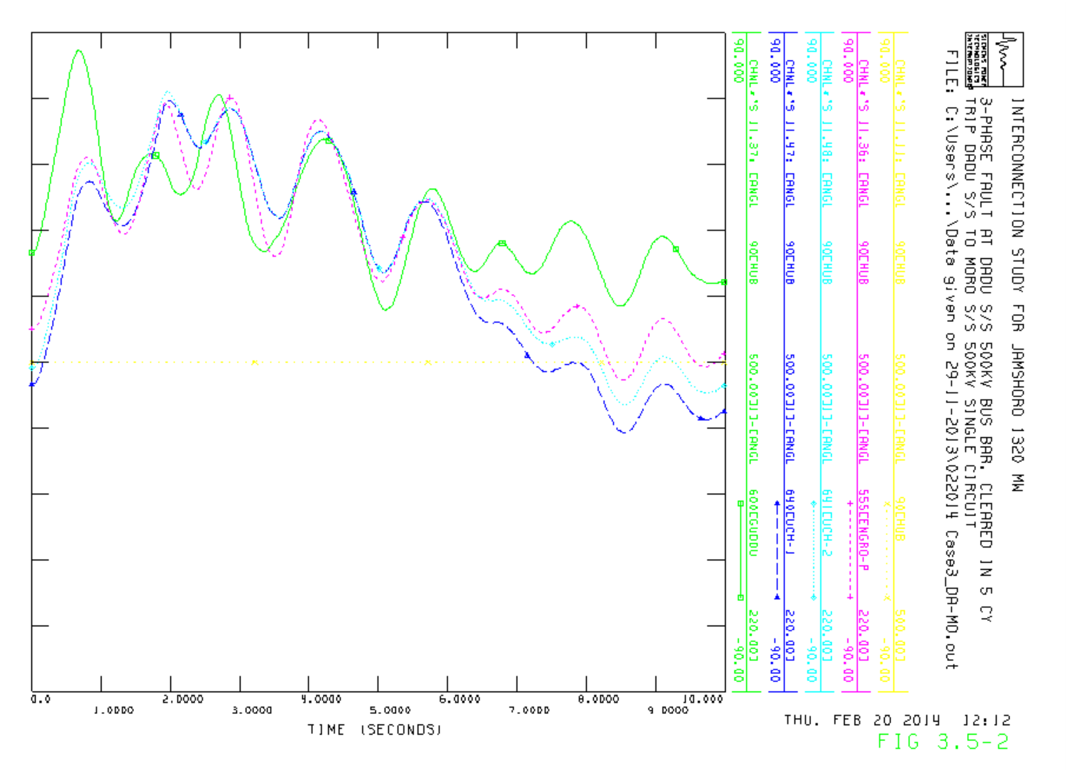




Case 3 (Qasim Case), Fault Section: Matiari S/S – Moro S/S

Transient Stability Analysis





Case 3 (Qasim Case), Fault Section: Dadu S/S – Moro S/S

Transient Stability Analysis

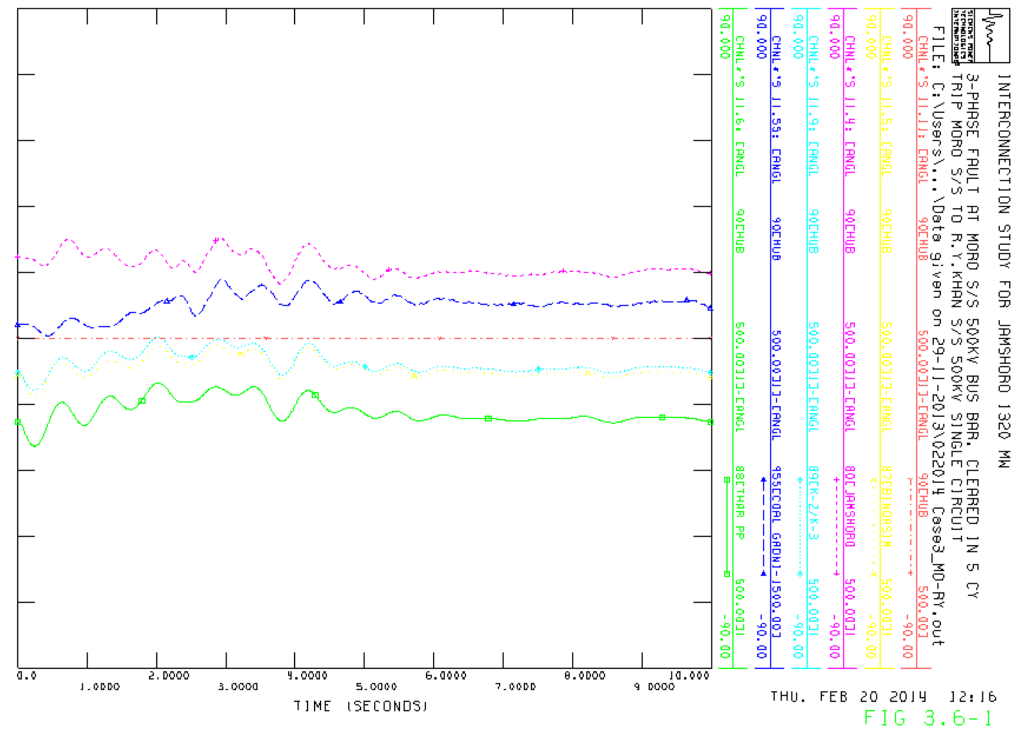


FIG 3.6-1

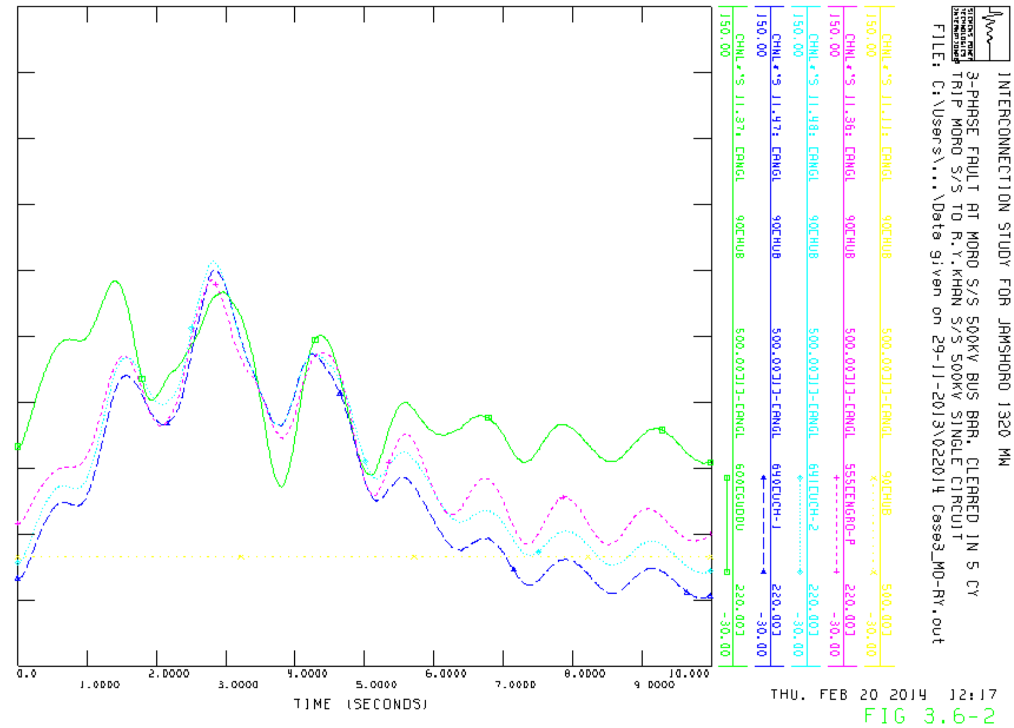
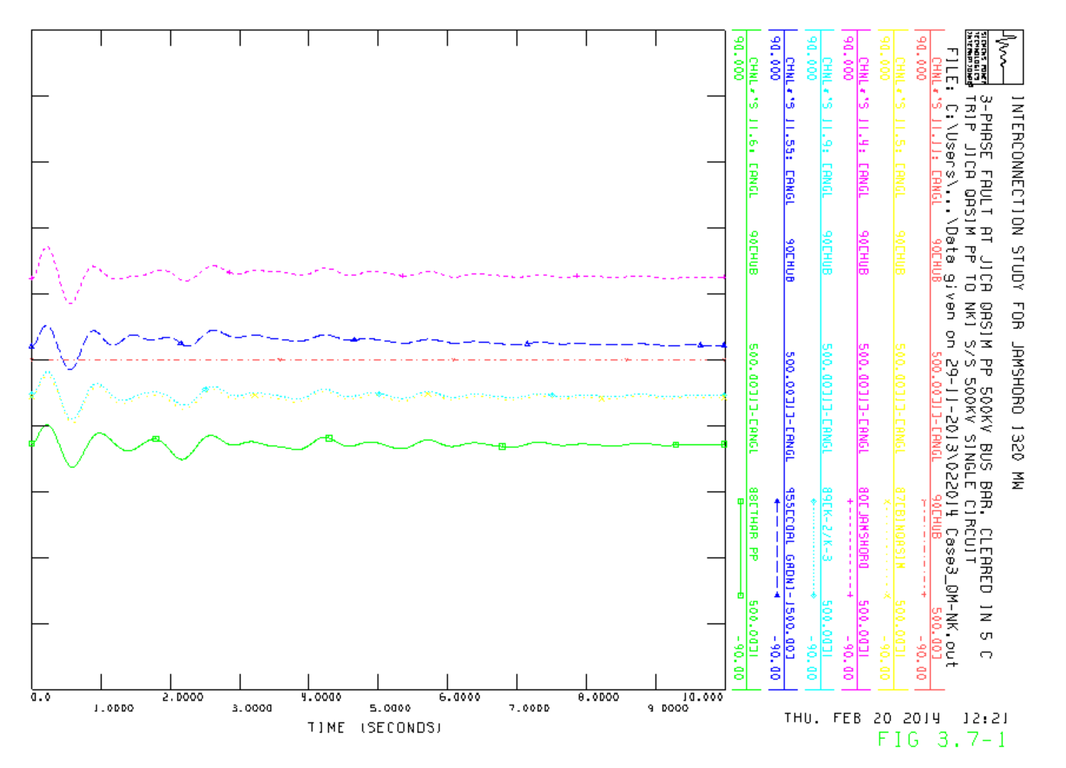
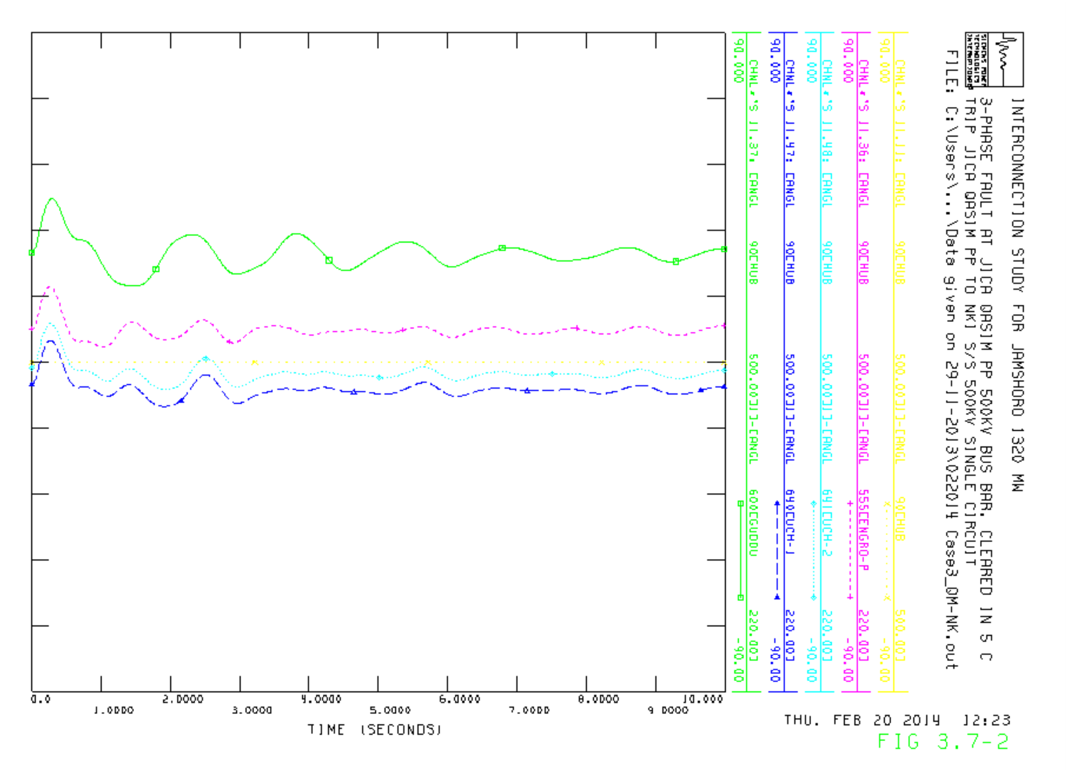


FIG 3.6-2

Case 3 (Qasim Case), Fault Section: Moro S/S – R. Y. Khan S/S

Transient Stability Analysis





Case 3 (Qasim Case), Fault Section: JICA Qasim CFPP – NKI S/S

3 - 4 POWER SYSTEM ANALYSIS IN ALTERNATIVE CASE (QASIM)

Power System Analysis in Alternative Case (Qasim)

A3.4.1 Outline of the Power System Analysis in Alternative Case

(1) Objectives of the Power System Analysis in Alternative Case

In transient stability analysis of JICA Lakhra case studied in Chapter 6, it was concluded that the proposed connection scheme for the proposed Lakhra power plant leads to instability in south system in the case of single circuit fault of some transmission sections.

Therefore, as alternative case, it needs to study another case (hereinafter referred to as Qasim case) that another CFPP in Qasim is connected to the transmission section between Gadani and Jamshoro via assumed new substation located 30km from JICA Qasim CFPP instead of JICA Lakhra power plant in order to verify whether instability in south system is improved or not.

In Qasim case, utilized power system analysis tool is the same as Lakhra case.

(2) Scope of the Study

Scopes of the study in Qasim case are the same as JICA Lakhra case mentioned in Chapter 6.

A3.4.2 Analysis Model

The analysis conditions and assumptions for both power flow and transient stability analyses were also the same as JICA Lakhra case except for the following items:

1) For the generator model of the new CFPP in Qasim, the generator constants of similar scale were applied.

2) The same type of the conductor as that of the existing line in the same section between substations was applied if reinforcement of the section(s) was/were necessary.

6) As the connection scheme from the existing 500kV transmission line to the proposed Qasim power plant, two-circuit π connection between Jamshoro – NKI and Jamshoro - Gadani line were assumed.

Power System Analysis in Alternative Case (Qasim)

A3.4.3 Power Flow Analysis

(1) Evaluation Criteria

The evaluation of the power flow analysis results were based on the transmission planning criteria (in terms of both the power flow and bus voltages), which were described in Chapter 3. The evaluation only covered the 500kV transmission system.

(2) Study Cases

Two study cases were set out depending on whether the Qasim CFPP exists or not as shown in Table A6.3-1. However, the result of power flow in PF-WQS is able to be assumed to refer to PF-WLK (without Lakhra CFPP) case studied in Section 6.3.2, Chapter 6.

Table A3.1 Power Flow Analysis Study Cases

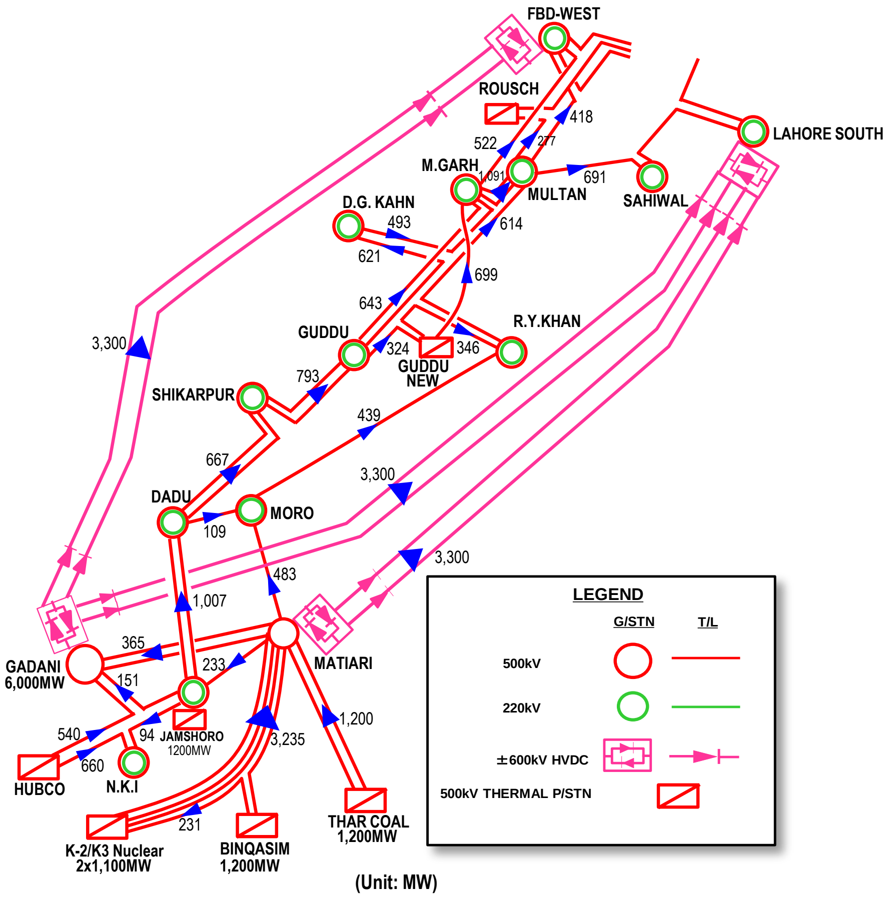
With/Without Qasim CFPP	Case Name
Without	PF-WQS
With	PF-QS

Source: JICA Survey Team

(3) Analysis Results

Under the normal operating condition, no overloading or voltage violation occurred to the 500kV power system in the South for both PF-QS and PF-WQS cases. The power flow diagrams for the normal operation condition are shown in Figure A3-1 and A-2, respectively. The PSS/E power flow diagrams are shown in Appendix 3.4.

Power System Analysis in Alternative Case (Qasim)

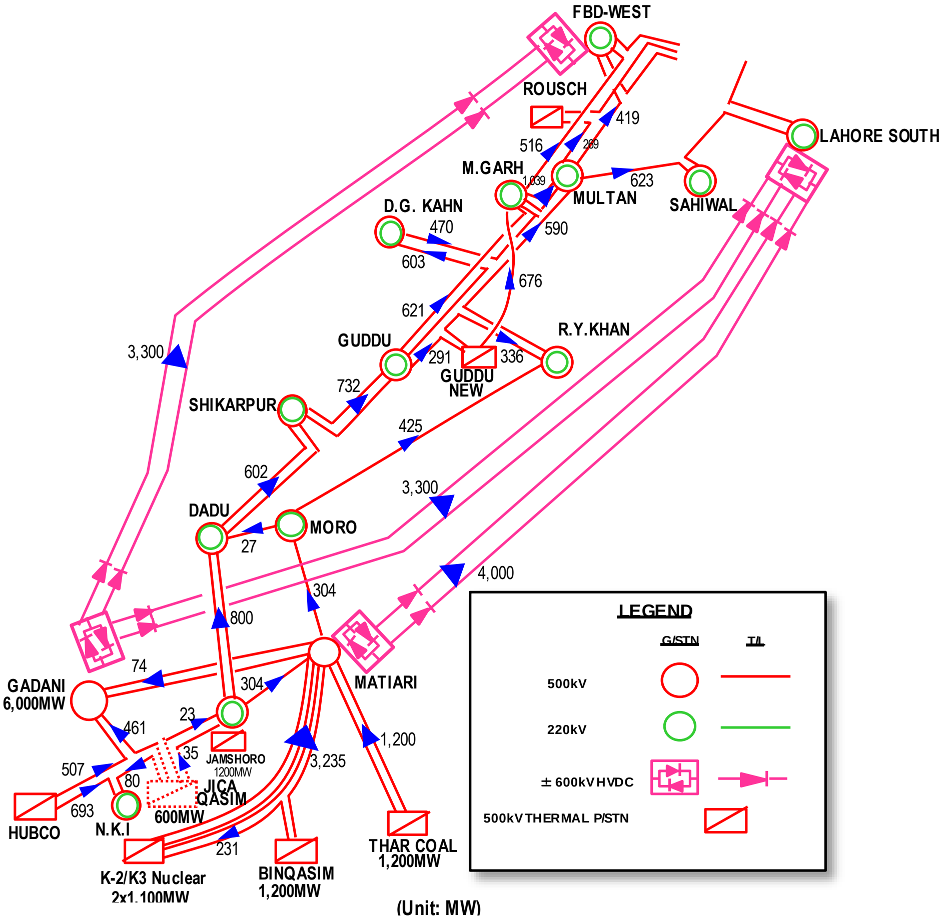


Source: JICA Survey Team

Figure: A3.1 Power Flow under Normal Operating Condition (Without Qasim CFPP (PF-WQS))

Under N-1 contingency condition, no overloading occurred to any section for both PF-WQS (without Qasim CFPP) case and PF-QS (with Qasim CFPP) case. There was no voltage violation for both PF-WQS and PF-QS cases.

Power System Analysis in Alternative Case (Qasim)



Source: JICA Survey Team

Figure: A3.2 Power Flow under Normal Operating Condition (With Qasim CFPP (PF-QS))

A3.4.4 Transient Stability Analysis

(1) Evaluation Criteria

The power system was considered “stable” if the amplitude of oscillation waveforms of the rotor phase angle difference between arbitrary two generators of the south system is likely to be damped and converged under N-1 contingency condition.

(2) Study Cases

Two study cases were set out depending on whether the Qasim CFPP exists or not as shown in Table A3.2. However, the result of transient stability analysis in ST-WQS is able to be assumed to refer to ST-WQS (without Lakhra CFPP) case studied in Section 6.4.2, Chapter 6.

Table A3.2 Transient Stability Analysis Analysis Study Cases

With/Without Qasim CFPP	Case Name
Without	ST-WQS
With	ST-QS

Source: JICA Survey Team

As the severe single contingency condition, a single circuit 3-phase short circuit fault at the sending end of the 500kV transmission sections between Jamshoro substation and Multan substations as well as those which were connected to Jamshoro and Matiari substations were selected.

The study cases and the fault sections are summarized in Table A3.3 The cells with "Y" indicate that the fault sections are relevant to the analysis for the study case in question.

The fault sequence which is the same as Lakhra case for the analysis is shown in Table A3.4. In Table A3.4, New S/S means the assumed switching station where is located 30km from JICA Qasim CFPP and connected to the section between Jamshoro – NKI line and Jamshoro-Gadani line by 2 π connection.

Power System Analysis in Alternative Case (Qasim)

Table A3.3 Study Cases

Fault Section \ Case	With Qasim PP	Without Qasim PP
Jamshoro - Gadani		Y
Jamshoro - NEW SS	Y	
NEW SS- NKI	Y	
NEW SS- JICA Qasim	Y	
Jamshoro - NKI		Y
Jamshoro - Dadu	Y	Y
Dadu - Moro	Y	Y
Matiari - Jamshoro	Y	Y
Matiari - Moro	Y	Y
Moro - R. Y. Khan	Y	Y
R. Y. Khan - Multan	Y	Y
Dadu - Shikarpur	Y	Y
Shikarpur - Guddu	Y	Y
Guddu - Muzaffargarh	Y	Y
Guddu - D. G. Khan	Y	Y
Guddu New - Muzaffargarh	Y	Y
Muzaffargarh - Multan	Y	Y

Y: Fault applicable for the case

Source: JICA Survey Team

Table A3.4 Fault Sequence

Time	Sequence
0 ms	3-phase short circuit fault occurred to a circuit of 500kV transmission line
100 ms	Clear fault and open the faulted circuit
10 s	End of calculation

Source: JICA Survey Team

(3) Study Results

The oscillation waveforms of the generator rotor phase angle difference between a generator of Muzaffagarh power plant and that of other principal power plants in the south system for all cases were shown in Appendix 3.4 (With Qasim Power Plant Case), respectively. The analysis results are summarized in Table A3.5.

Power System Analysis in Alternative Case (Qasim)

Table A3.5 Transient Stability Analysis Results

Fault Section \ Case	With Qasim PP	Without Qasim P/S
Jamshoro - Gadani		Stable
Jamshoro - NEW SS	Unstable	
NEW SS- NKI	Stable	
NEW SS- JICA Qasim	Stable	
Jamshoro - NKI		Stable
Jamshoro - Dadu	Unstable	Stable
Dadu - Moro	Stable	Stable
Matiari - Jamshoro	Unstable	Stable
Matiari - Moro	Unstable	Stable
Moro - R. Y. Khan	Stable	Stable
R. Y. Khan - Multan	Stable	Stable
Dadu - Shikarpur	Stable	Stable
Shikarpur - Guddu	Stable	Stable
Guddu - Muzaffargarh	Stable	Stable
Guddu - D. G. Khan	Stable	Stable
Guddu New - Muzaffargarh	Stable	Stable
Muzaffargarh - Multan	Stable	Stable

Source: JICA Survey Team

For "With Qasim" power plant case, the system became unstable when a single circuit fault occurred to any sections from/to HUBCO substation, Matiari switching station, and Qasim power plant.

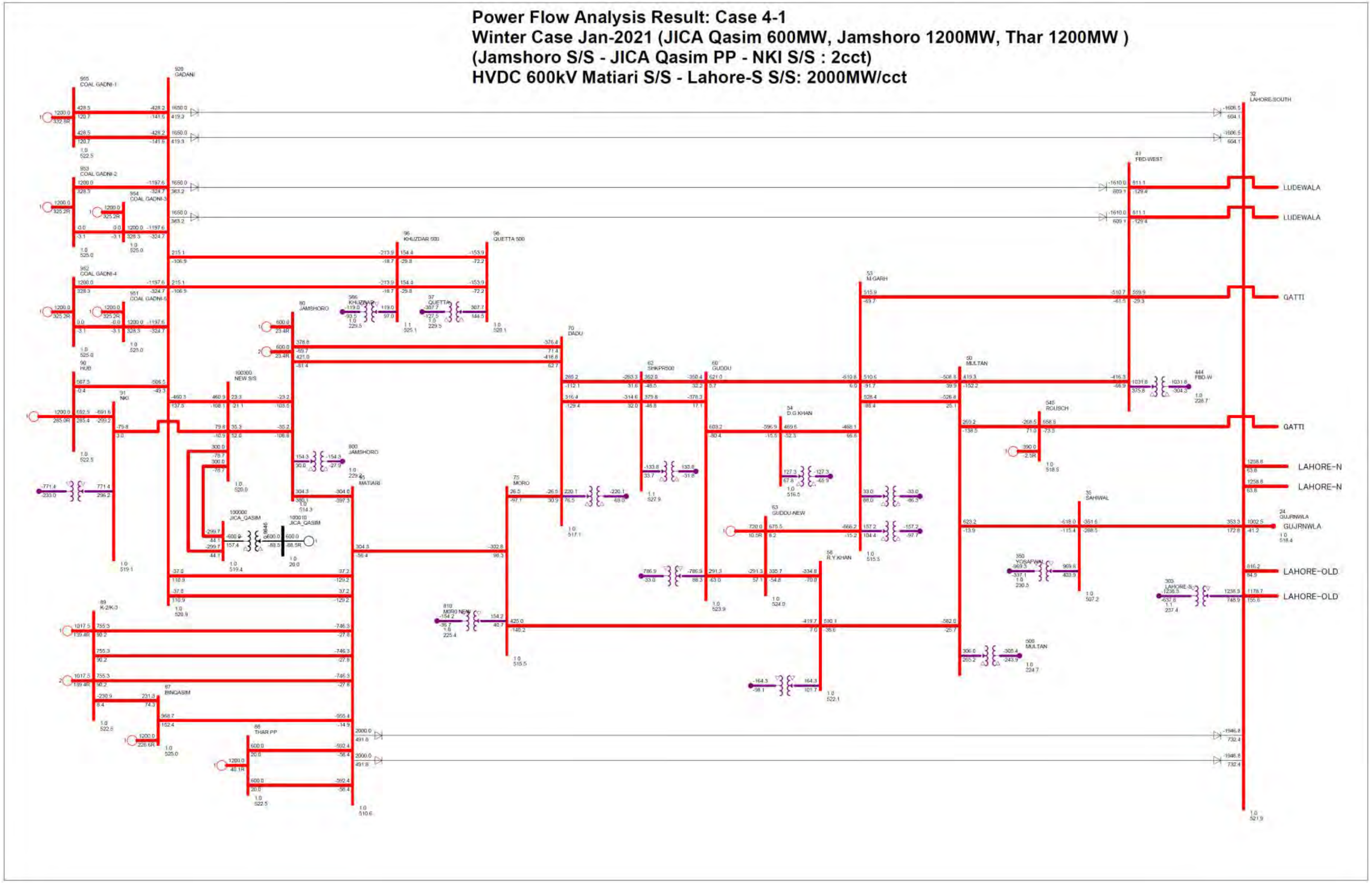
A3.4.5 Conclusions

As the results of power flow and transient stability analyses, it is concluded that the proposed connection scheme for the proposed Qasim power plant also leads to instability in south system in the case of single circuit fault of some transmission sections.

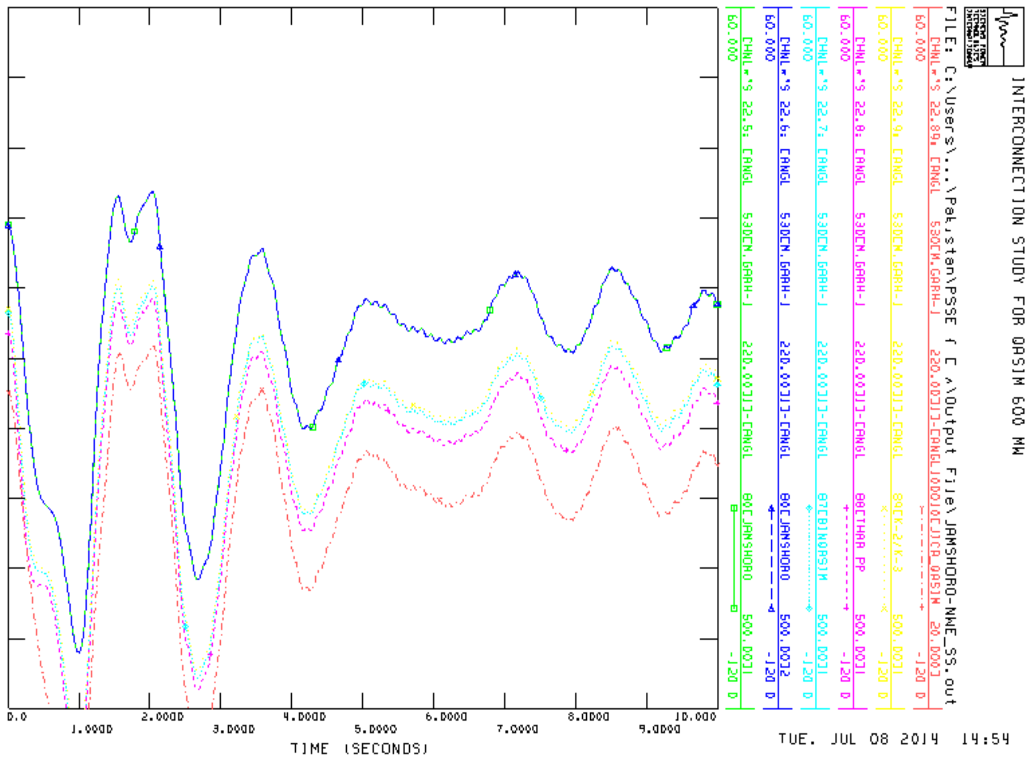
More detail about analysis result is described in Appendix 3.5.

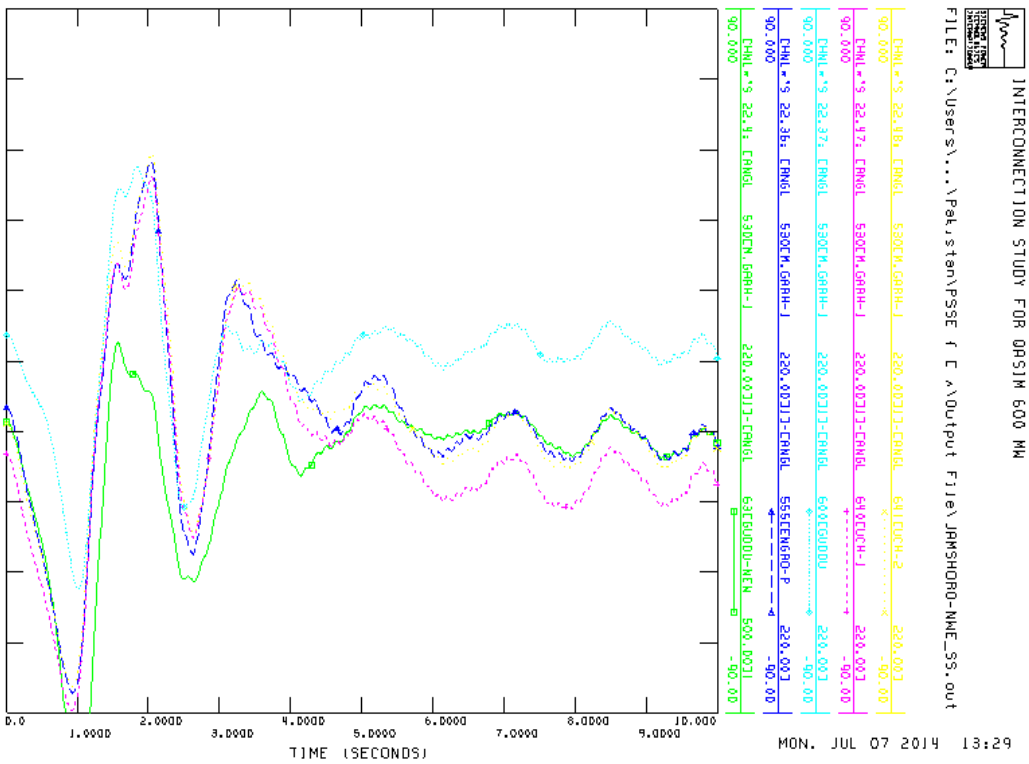
3 - 5 POWER SYSTEM ANALYSIS RESULTS (WITH QASIM POWER PLANT CASE)

Appendix3-5 Power System Analysis Results (With Qasim Power Plant Case)



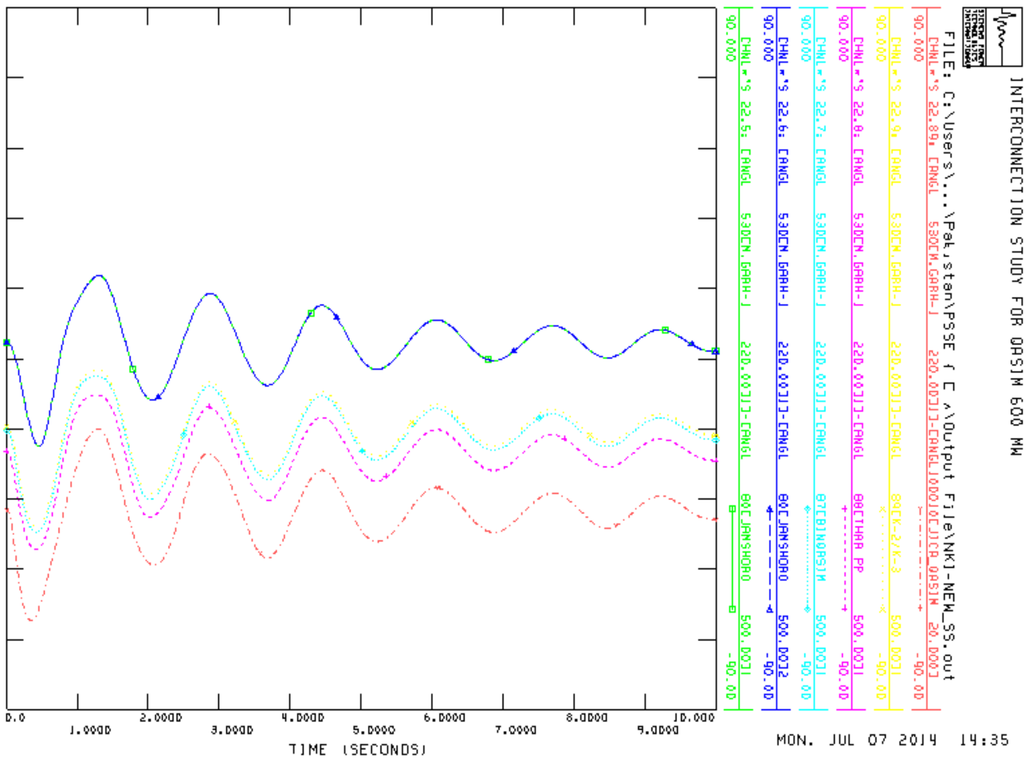
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

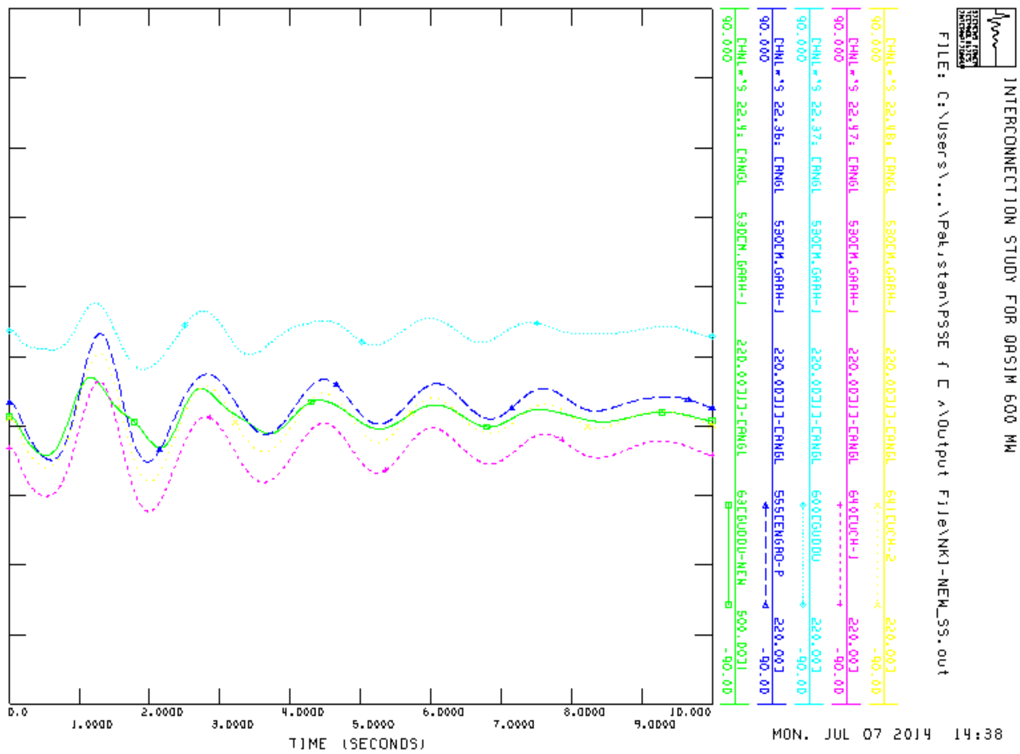




Fault Section: Jamshoro S/S – JICA Lakhra PP

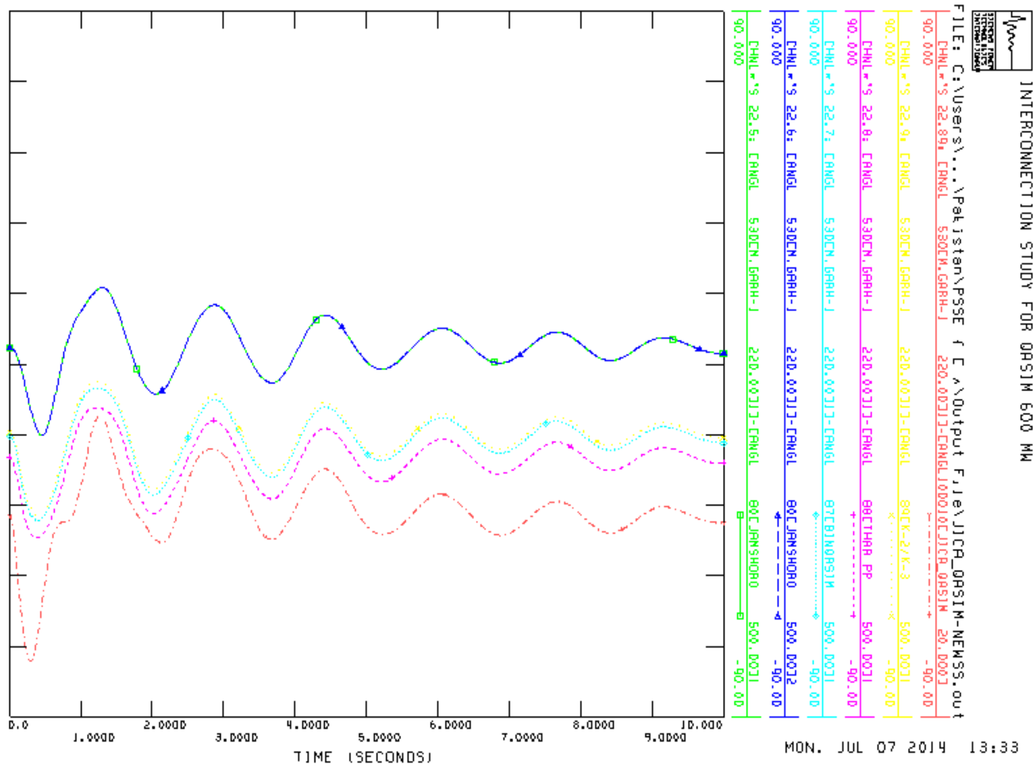
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

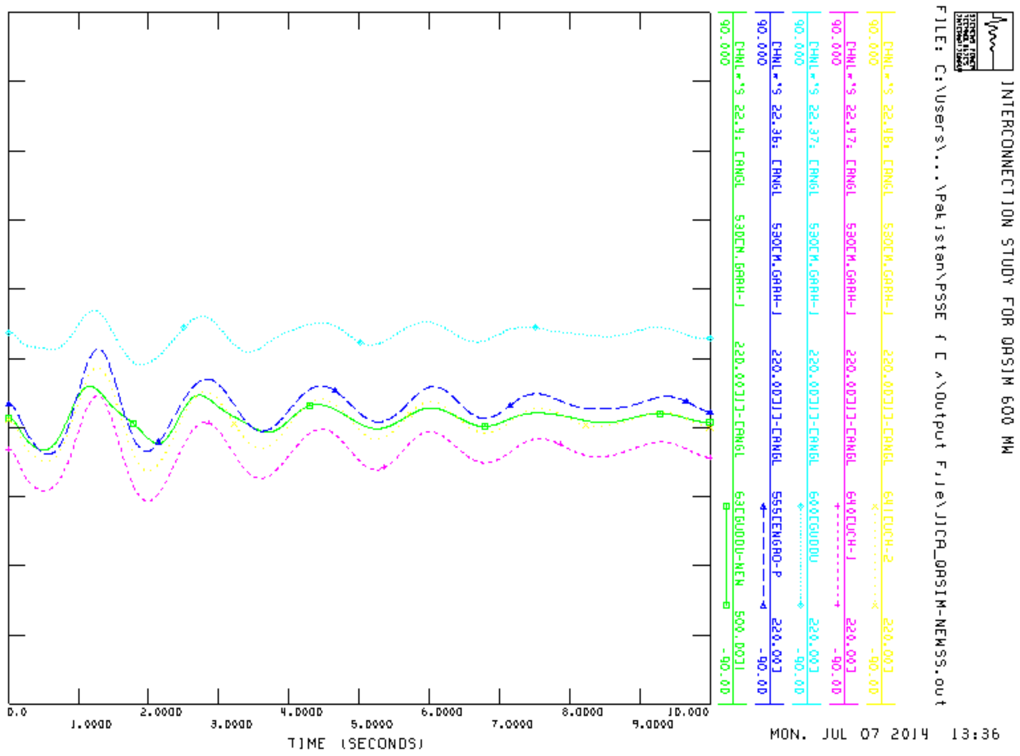




Fault Section: NKI S/S – New S/S

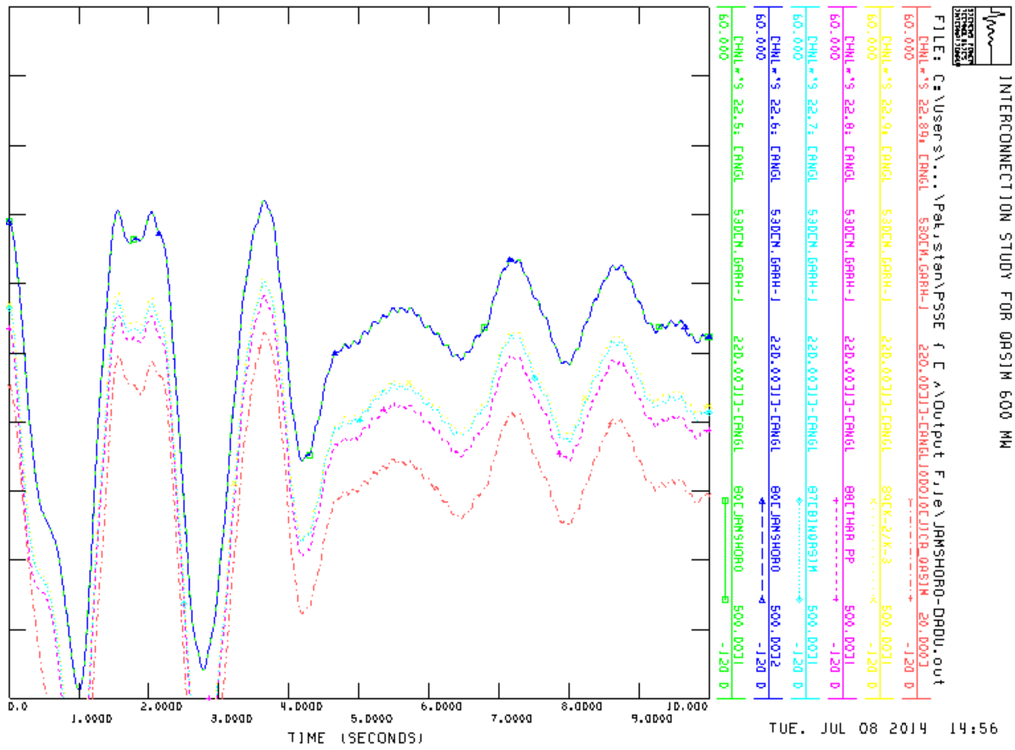
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

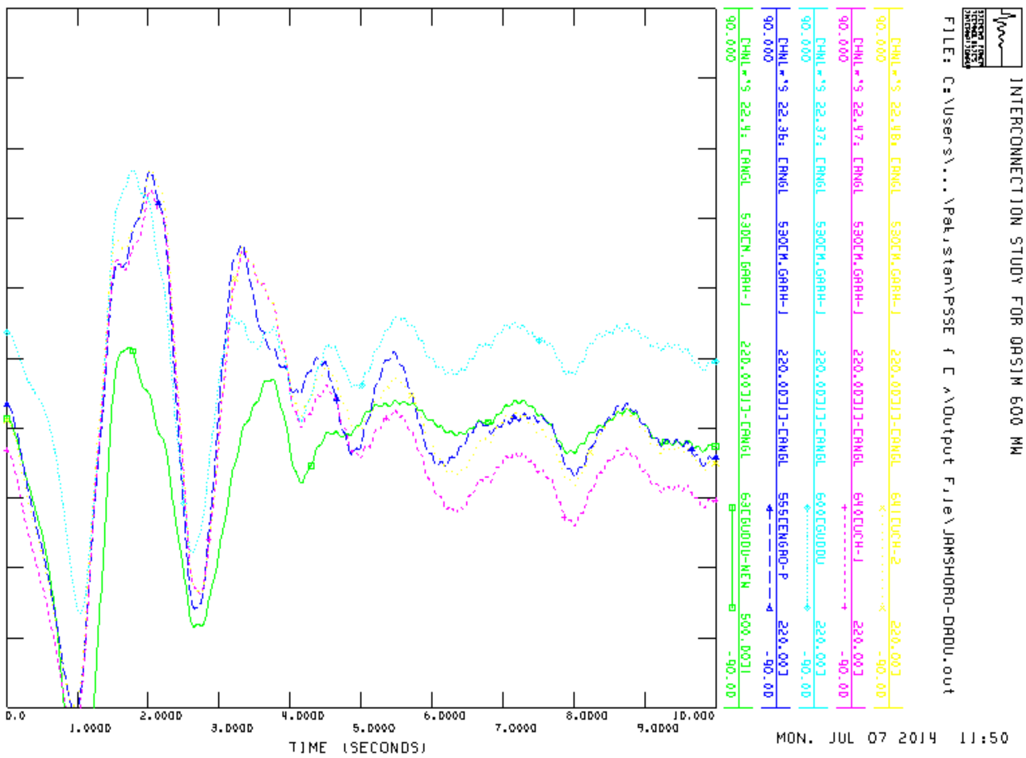




Fault Section: JICA Qasim PP – New S/S

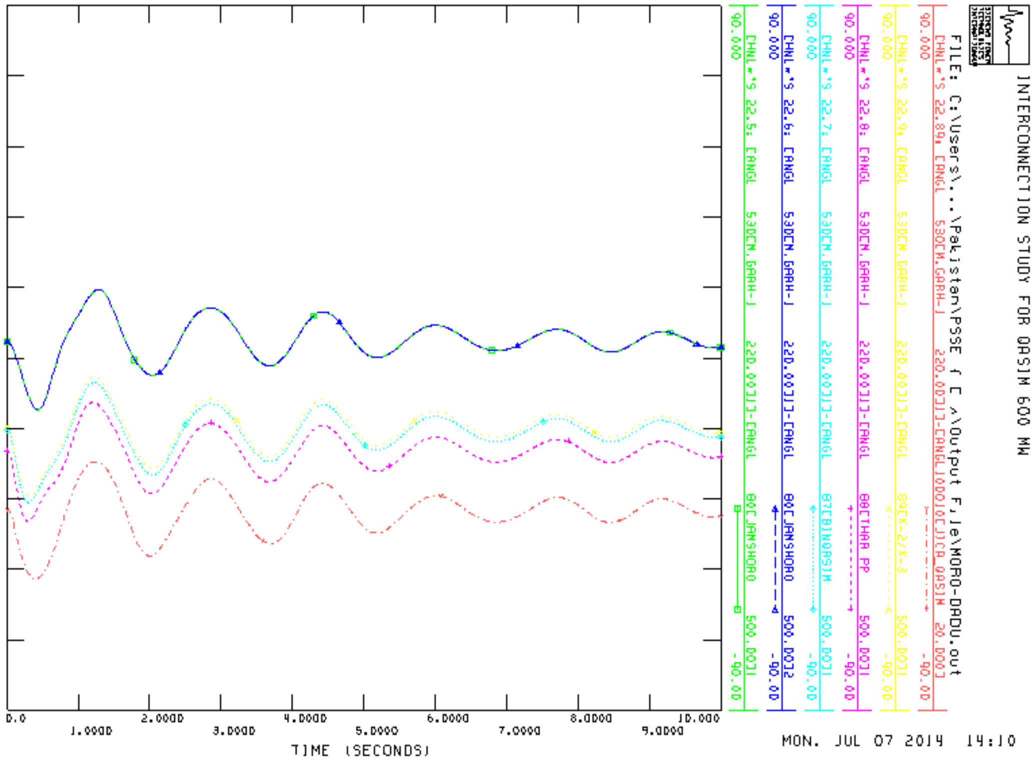
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

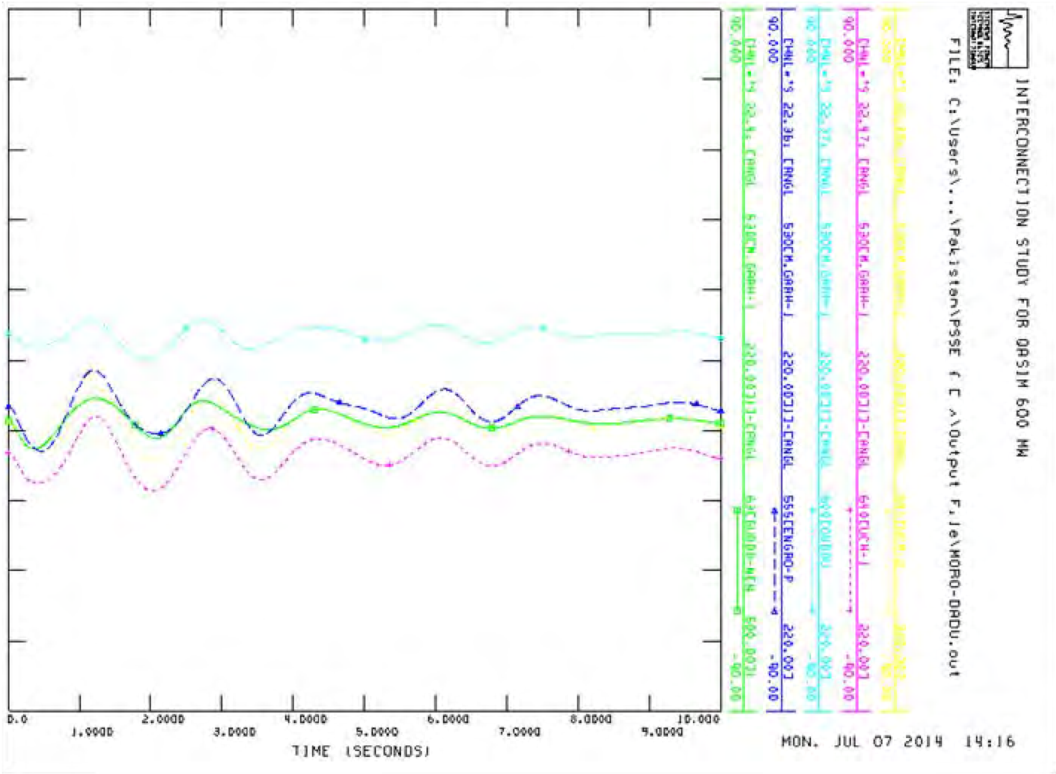




Fault Section: Jamshoro S/S – Dadu S/S

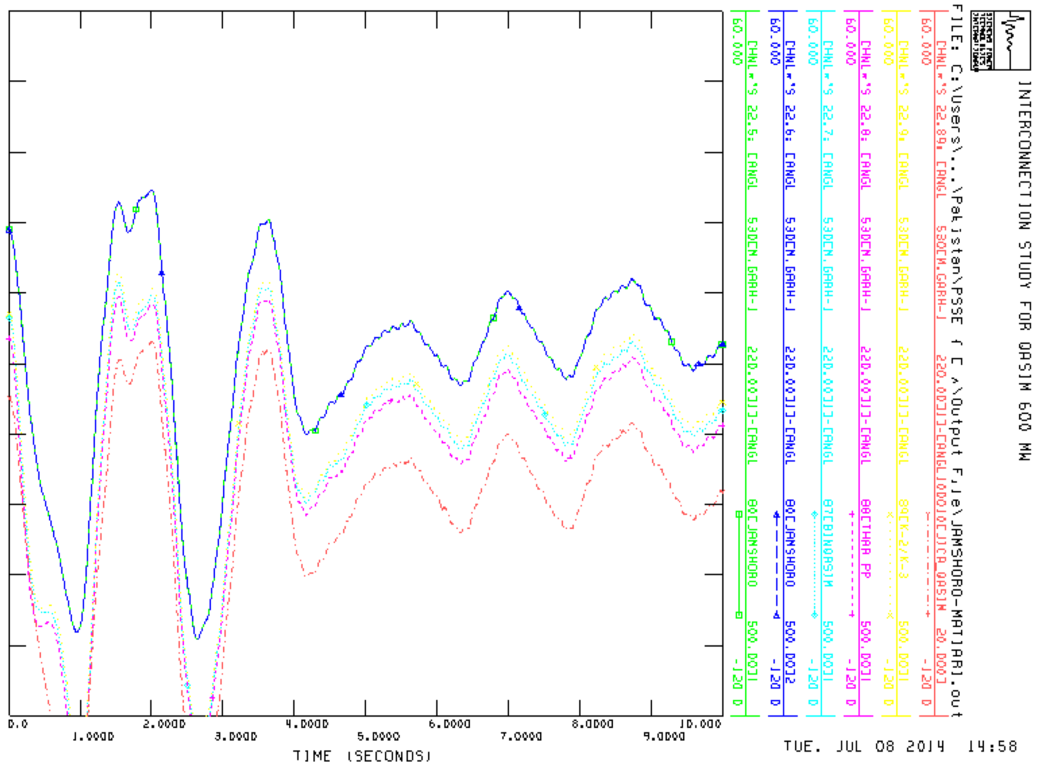
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

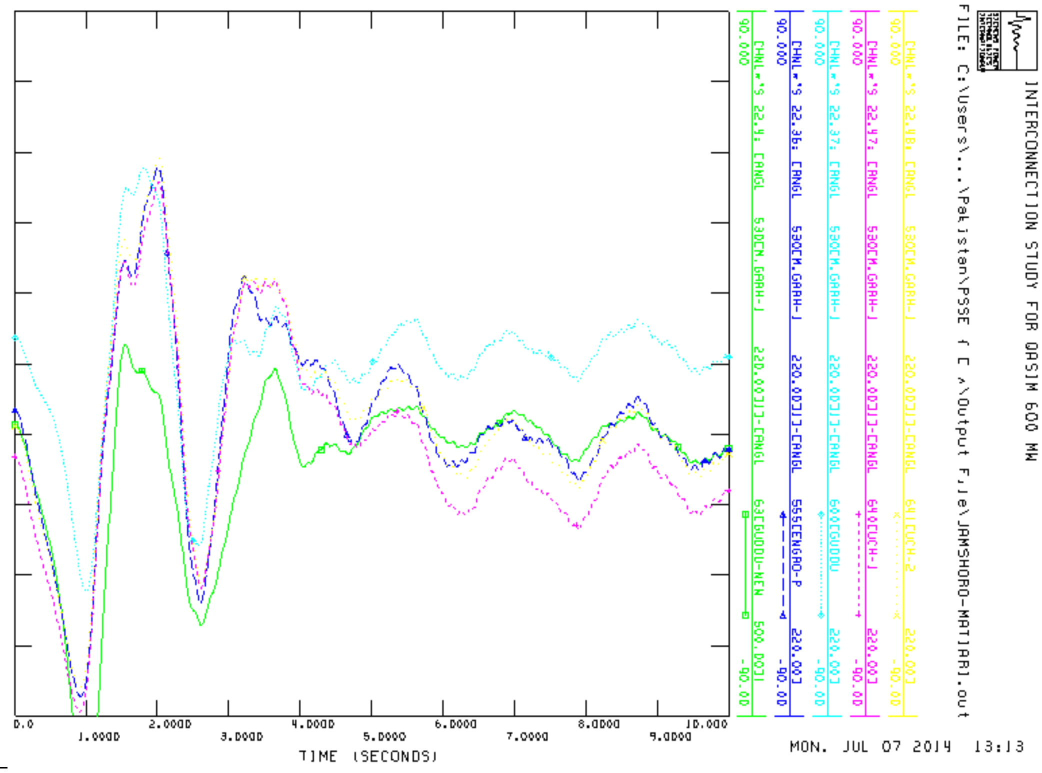




Fault Section: Dadu S/S – Moro S/S

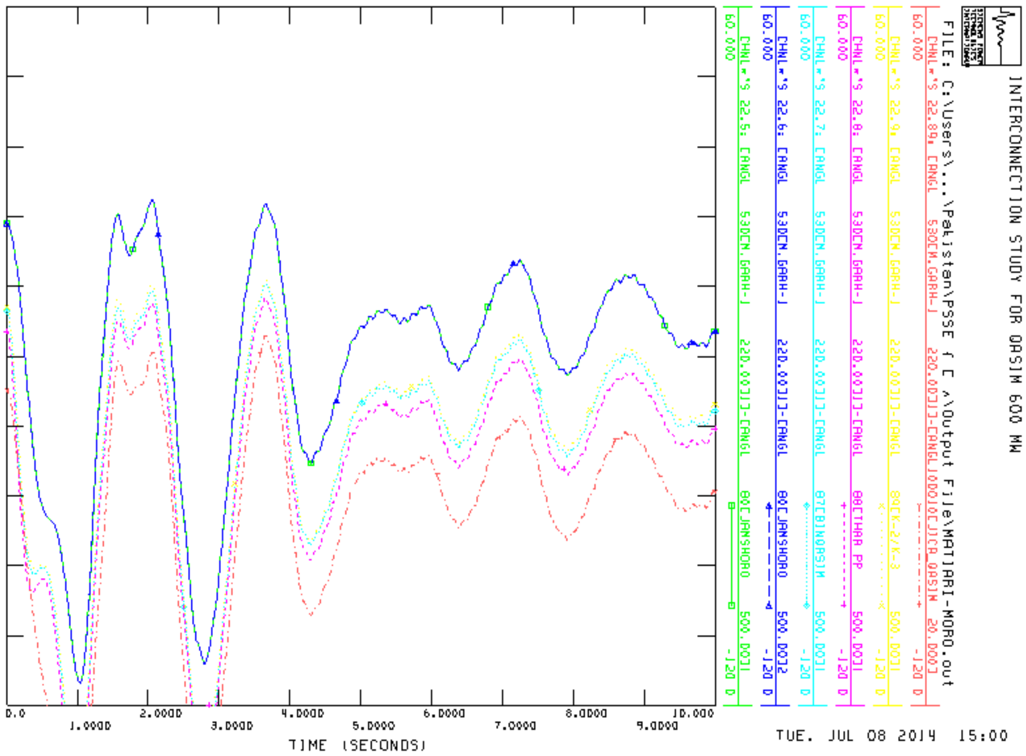
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

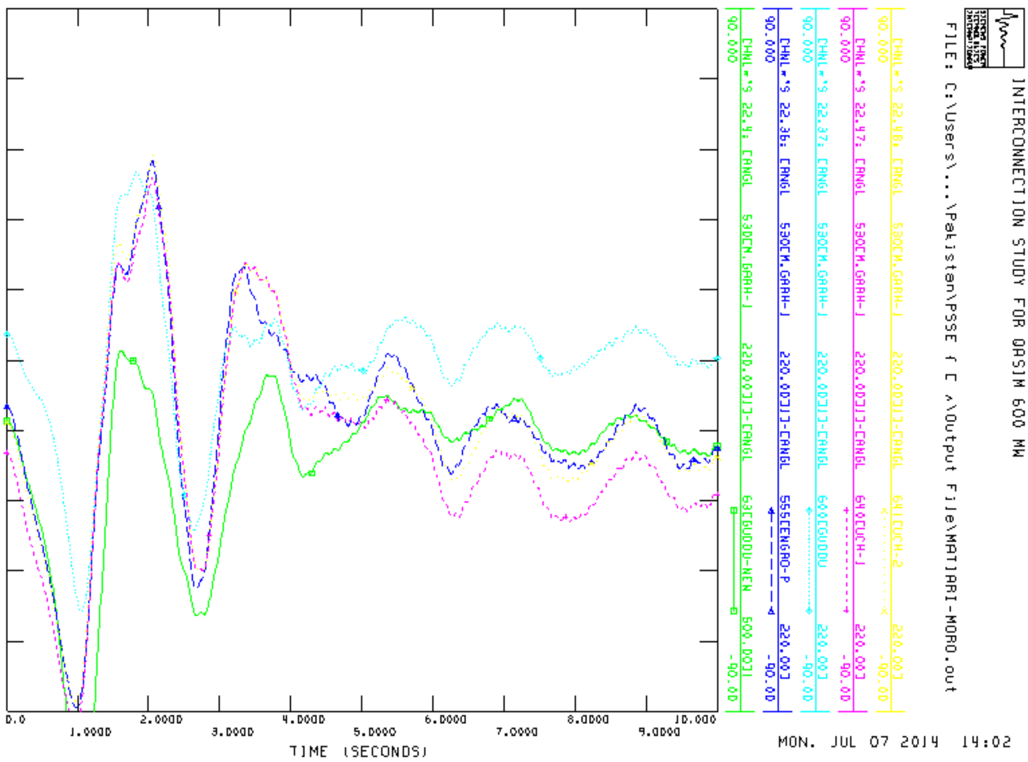




Fault Section: Matiari S/S – Jamshoro S/S

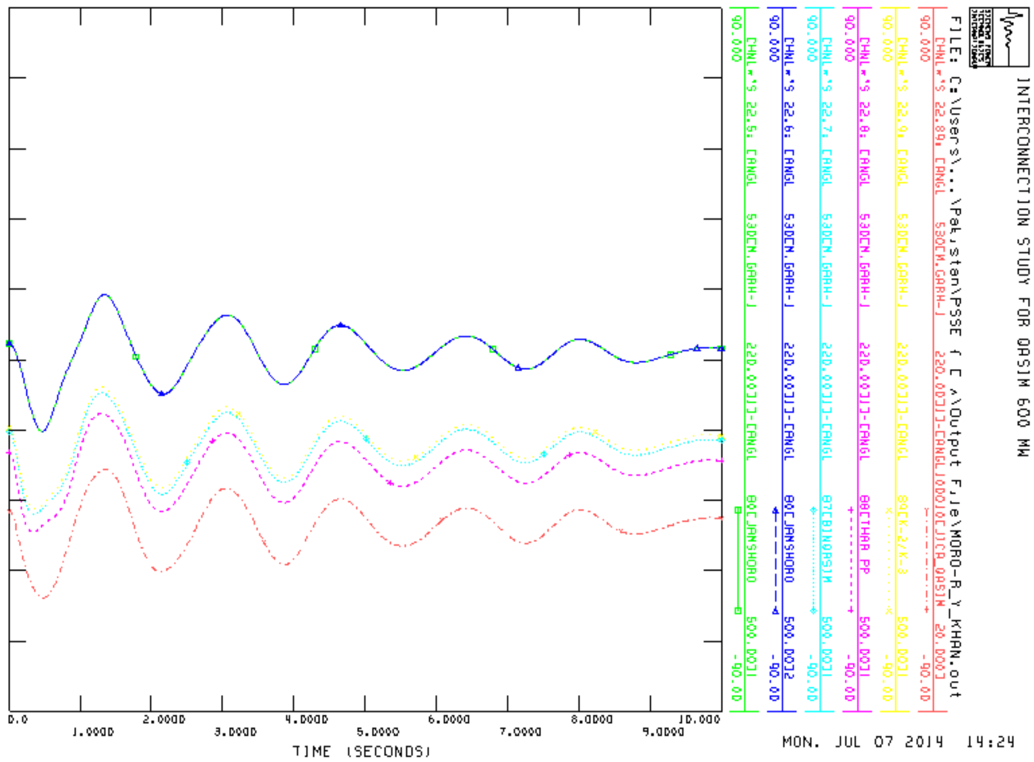
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

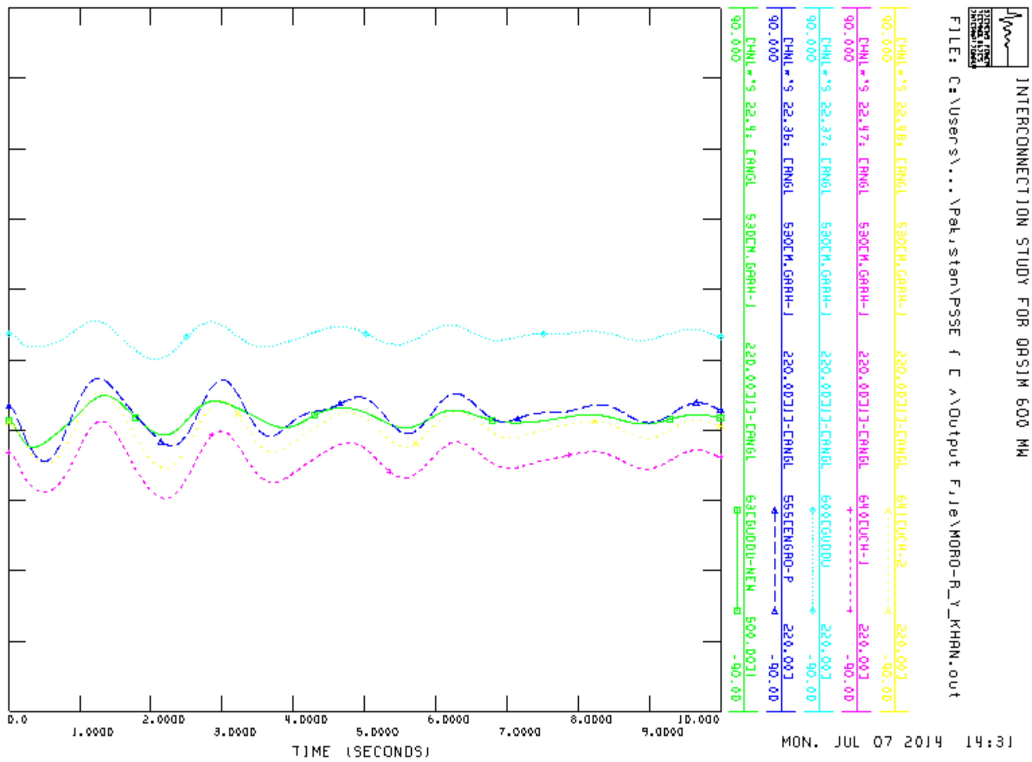




Fault Section: Matiari S/S – Moro S/S

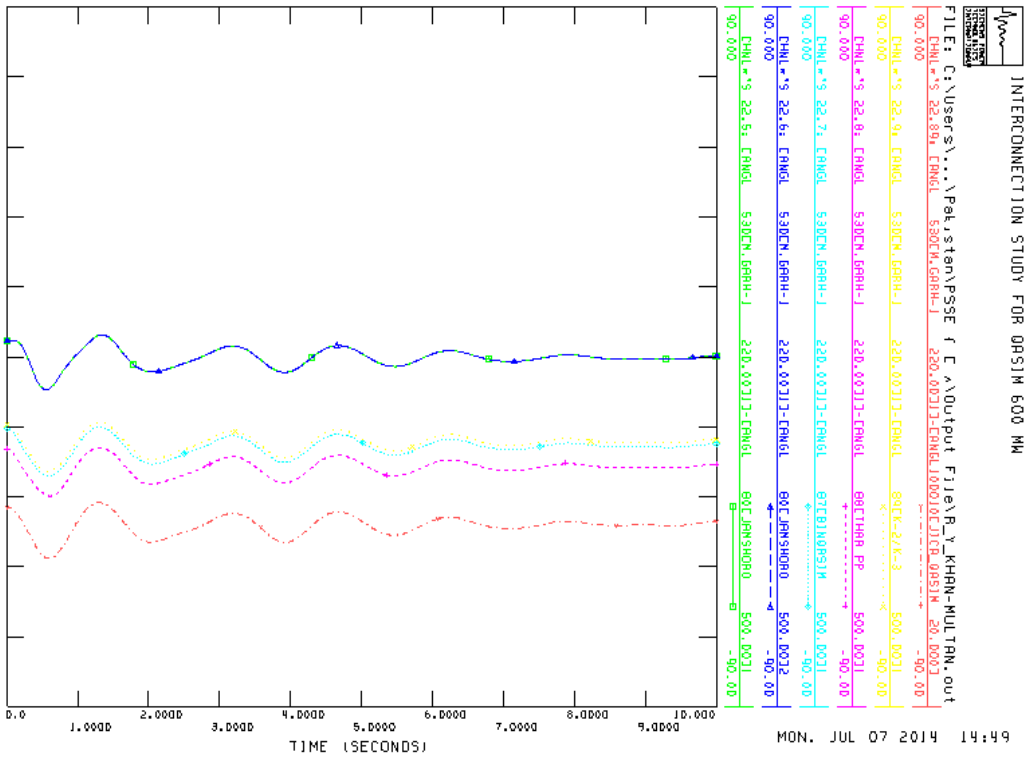
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

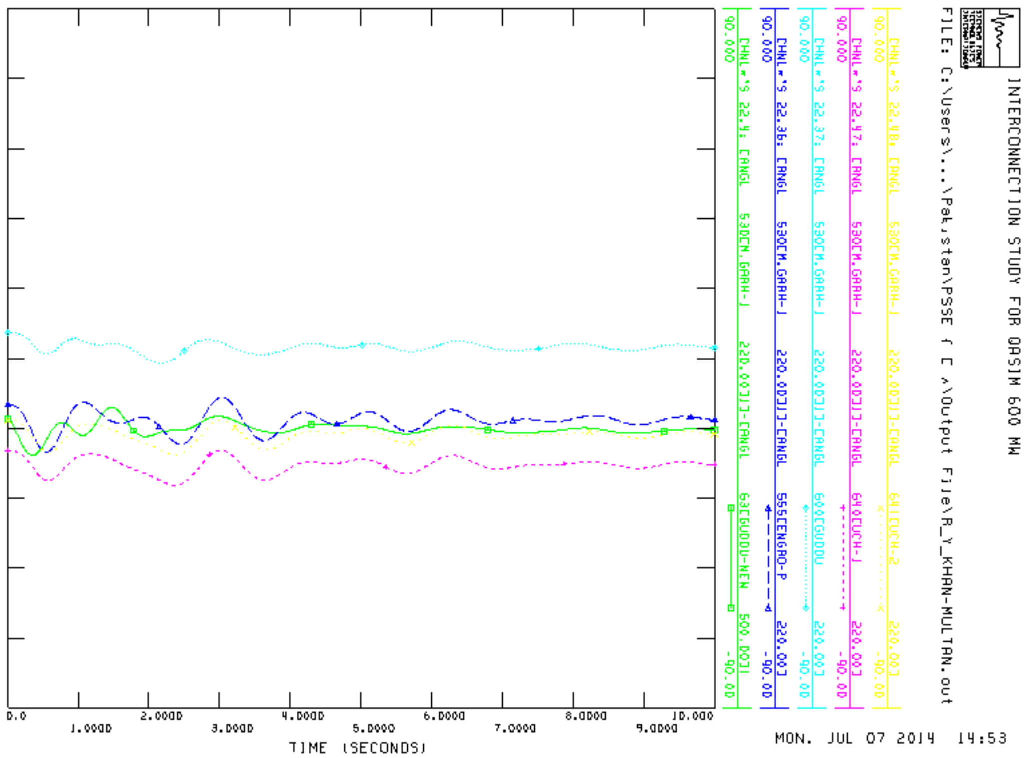




Fault Section: Moro S/S – R. Y. Khan S/S

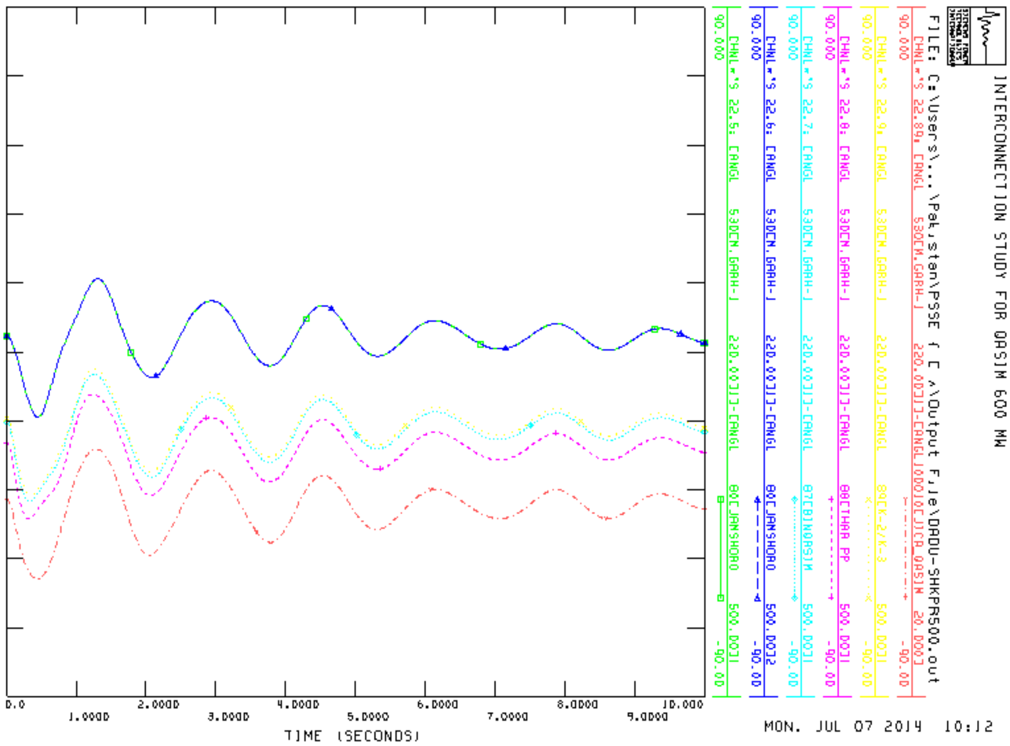
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

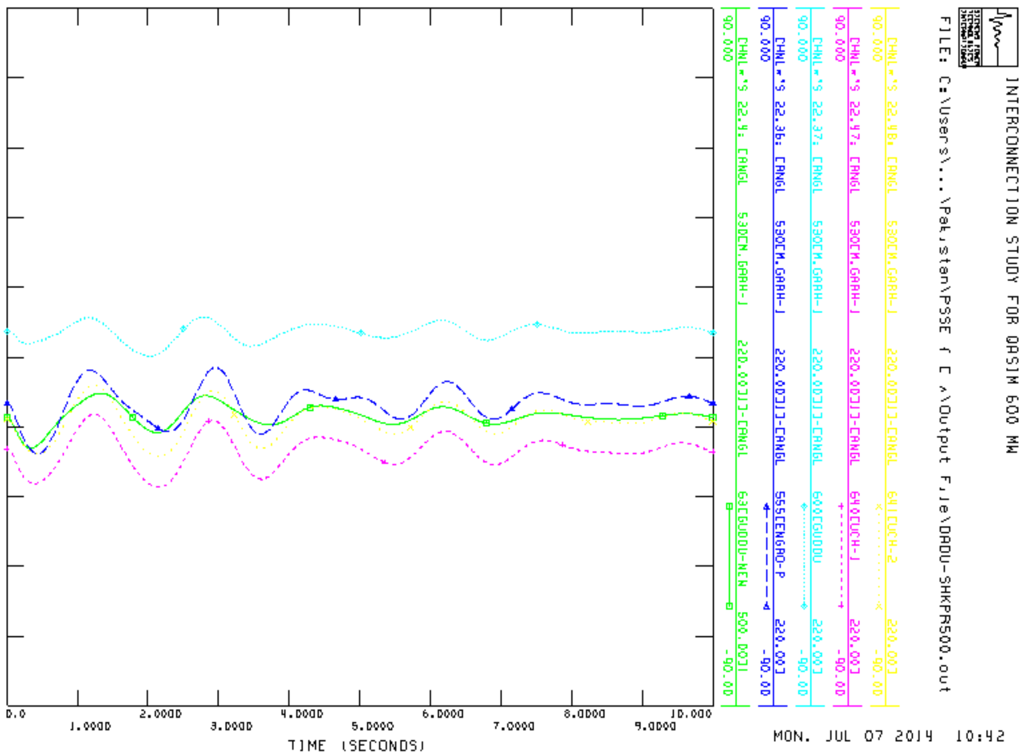




Fault Section: R. Y. Khan S/S – Multan S/S

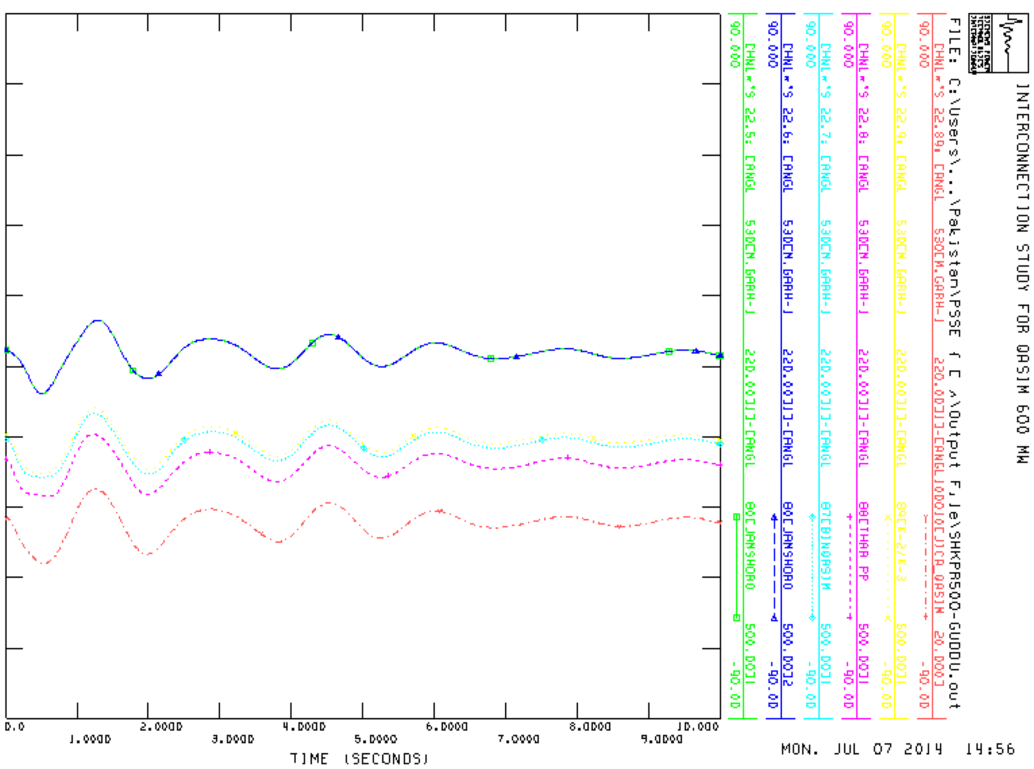
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

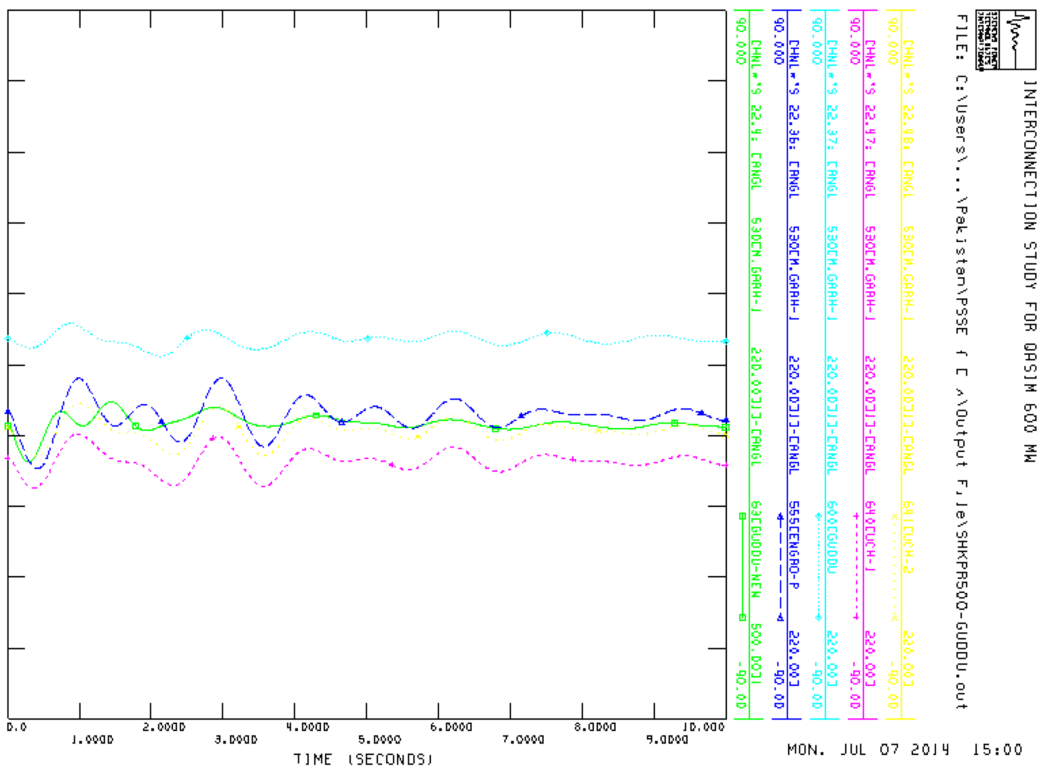




Fault Section: Dadu S/S – Shikarpur S/S

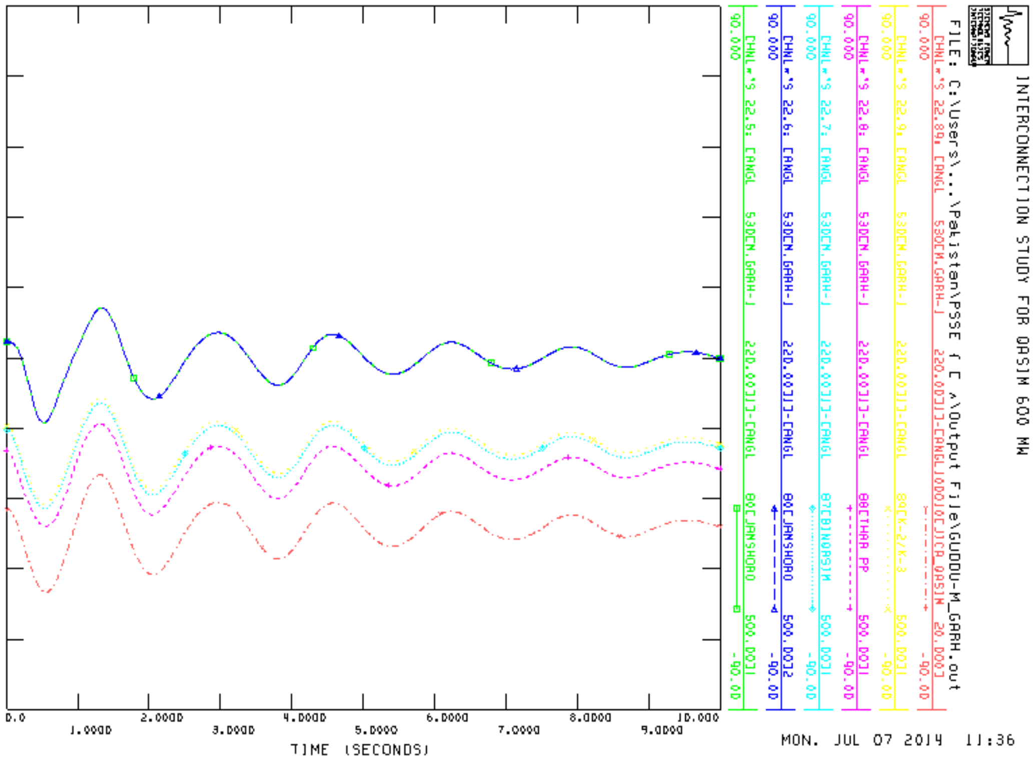
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

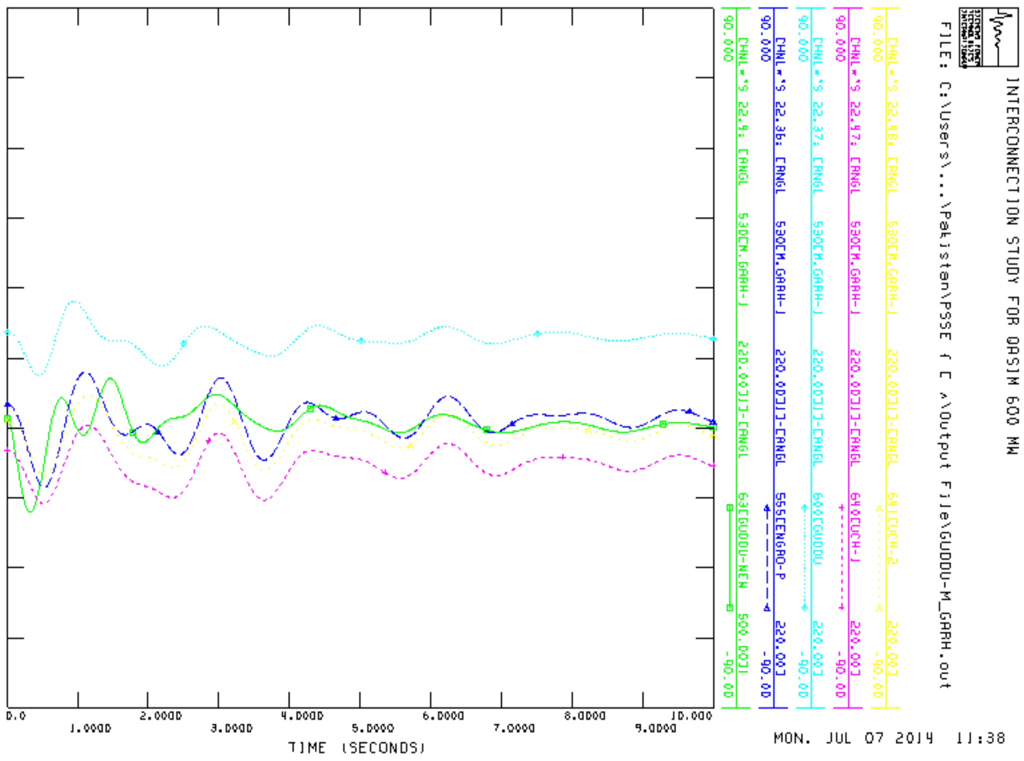




Fault Section: Shikarpur S/S – Guddu S/S

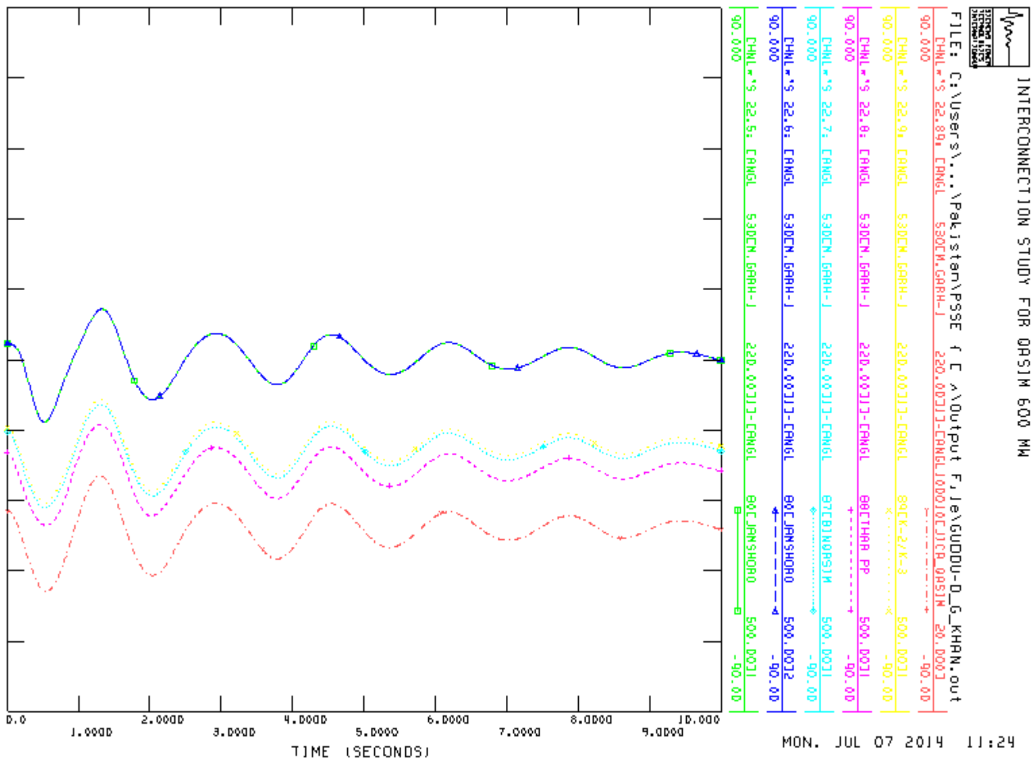
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

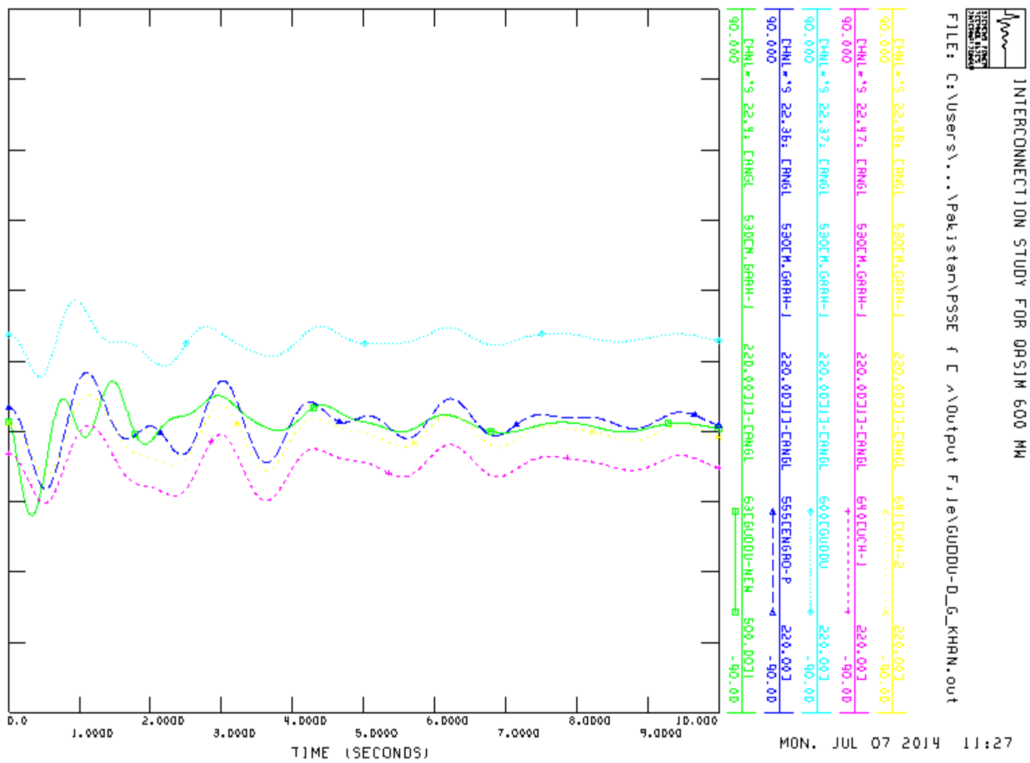




Fault Section: Guddu S/S – Muzaffargarh S/S

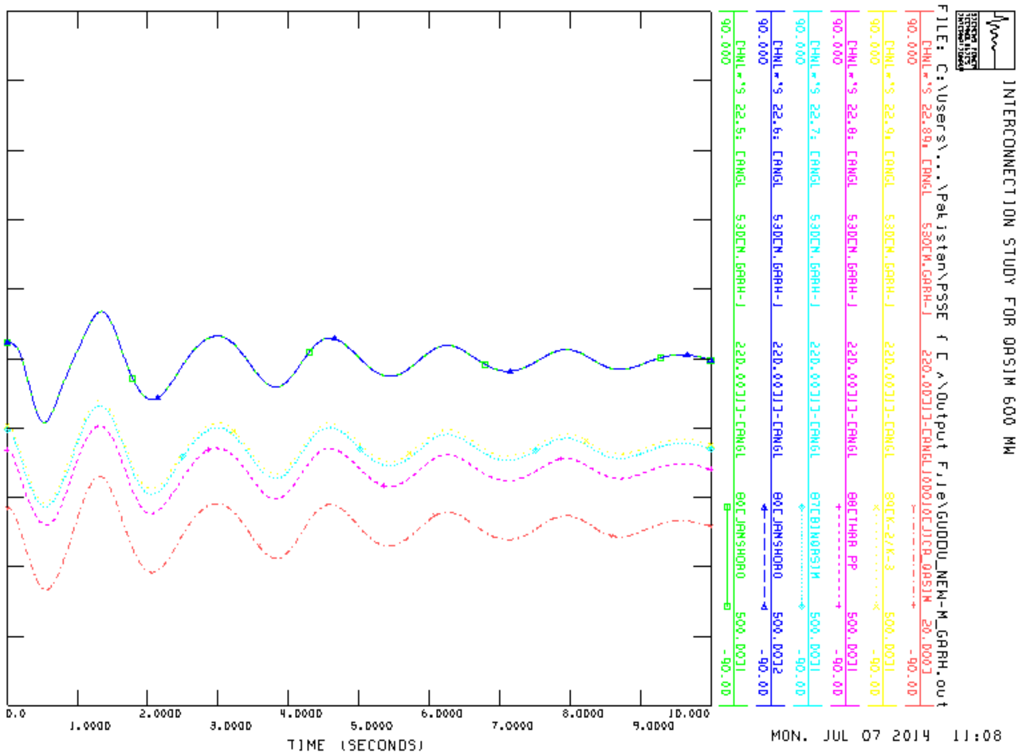
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

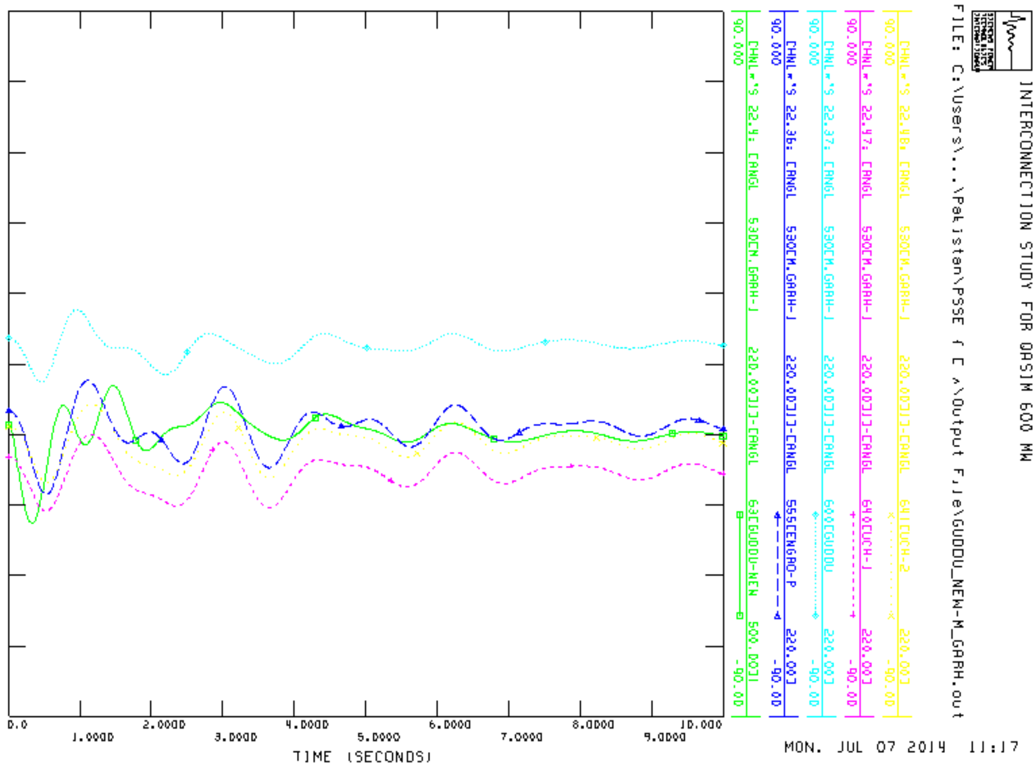




Fault Section: Guddu S/S – D. G. Khan S/S

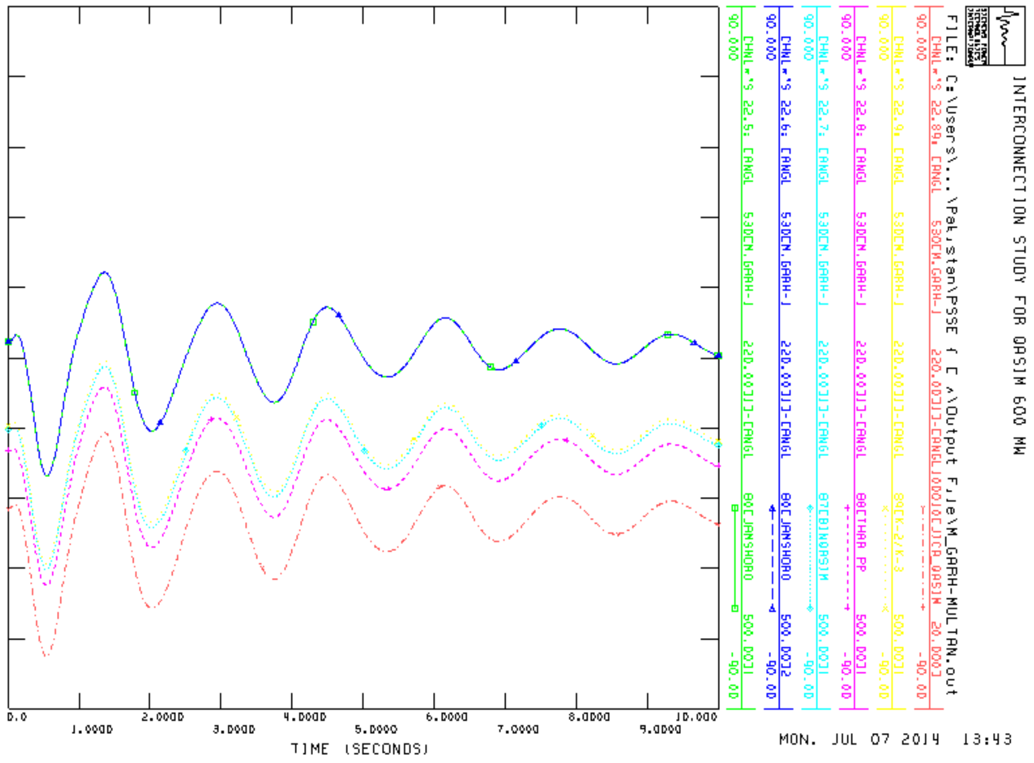
Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)

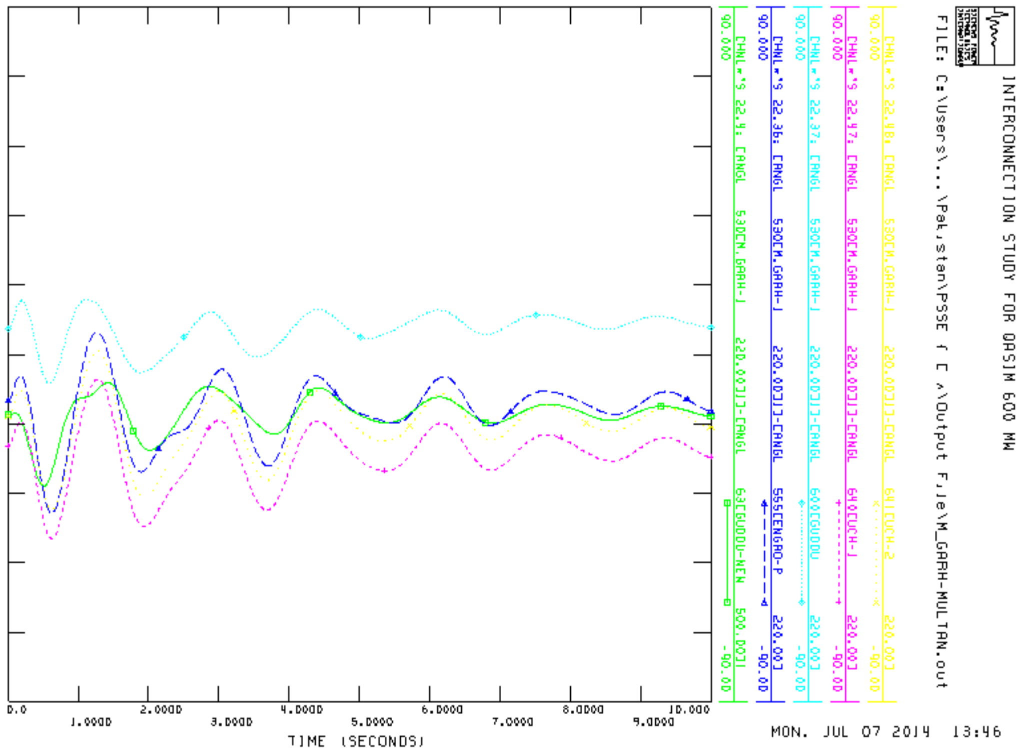




Fault Section: Guddu New PP – Muzaffargarh S/S

Appendix3-5 Power Flow Diagram (With Qasim Power Plant Case)





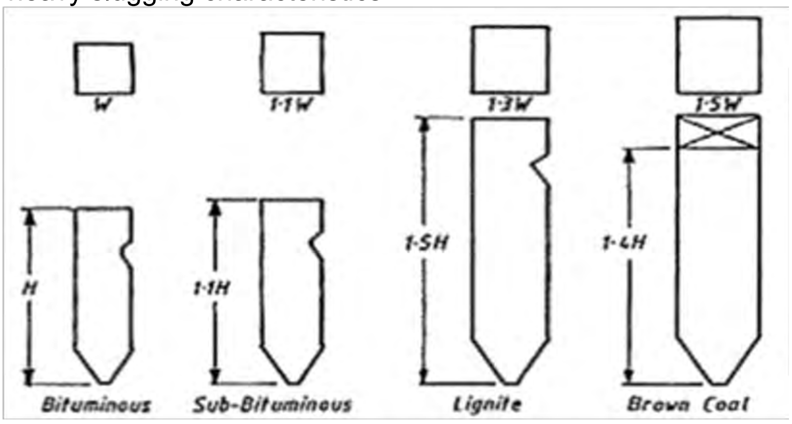
Fault Section: Muzaffargarh S/S – Multan S/S

3 - 6 COMPARISON OF BOILER SIZE

Comparison of Boiler Size

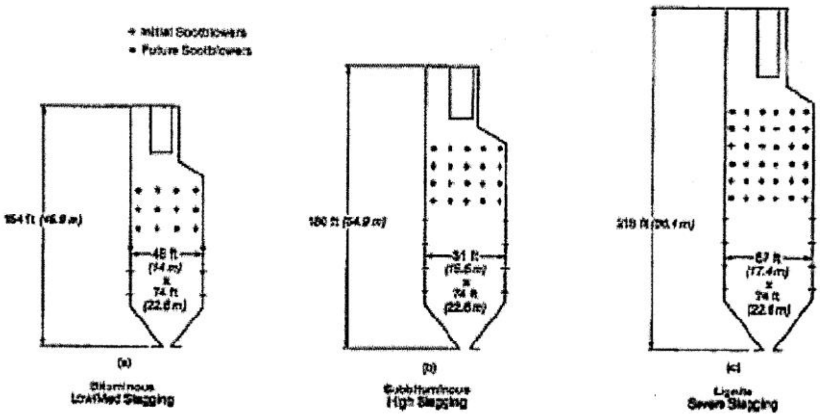
Comparisons of boiler sizes for Bituminous, Sub-Bituminous, Lignite and Brown coal are as follows.

1) In case of using Australian Latrobe Valley coal, which have the heavy slugging characteristics



Volume rate 1 : 1.3 : 2.5 : 3.2

2) In case of coals in U.S.A (by B&W USA)



	Bituminous		Subbtuminous		Lignite
Volume rate	1	:	1.3	:	1.8

Lignite boiler, in general, has the slugging characteristics.

As for the countermeasure, firing temperature is decreased, but it requires long firing time, so the size of Lignite boiler is larger than Bituminous.

3 - 7 METEOROLOGICAL DATA

Meteorological Data in accordance with condenser cooling

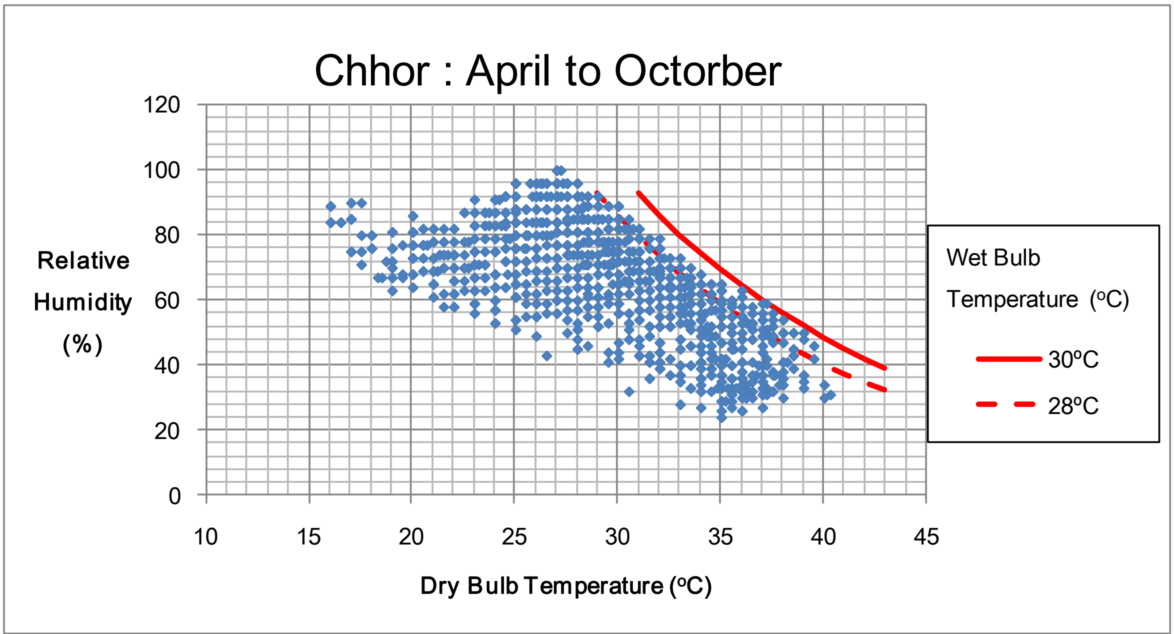
As the condenser is cooled by the cooling water, wet bulb temperature and sea water temperature, which decisively affect the cooling water temperature, are surveyed.

(1) Wet Bulb Temperature in Chhor near Thar

For the case of cooling tower, wet bulb temperature is a main parameter to control the temperature of cooling water to the condenser.

It is recognized in Figure 3.4-1, when dry bulb temperature is high, relative humidity is low and the highest wet bulb temperature is about 30 °C.

According to the above characteristics design wet bulb temperature is selected of 28 °C.



Source: JICA Survey Team

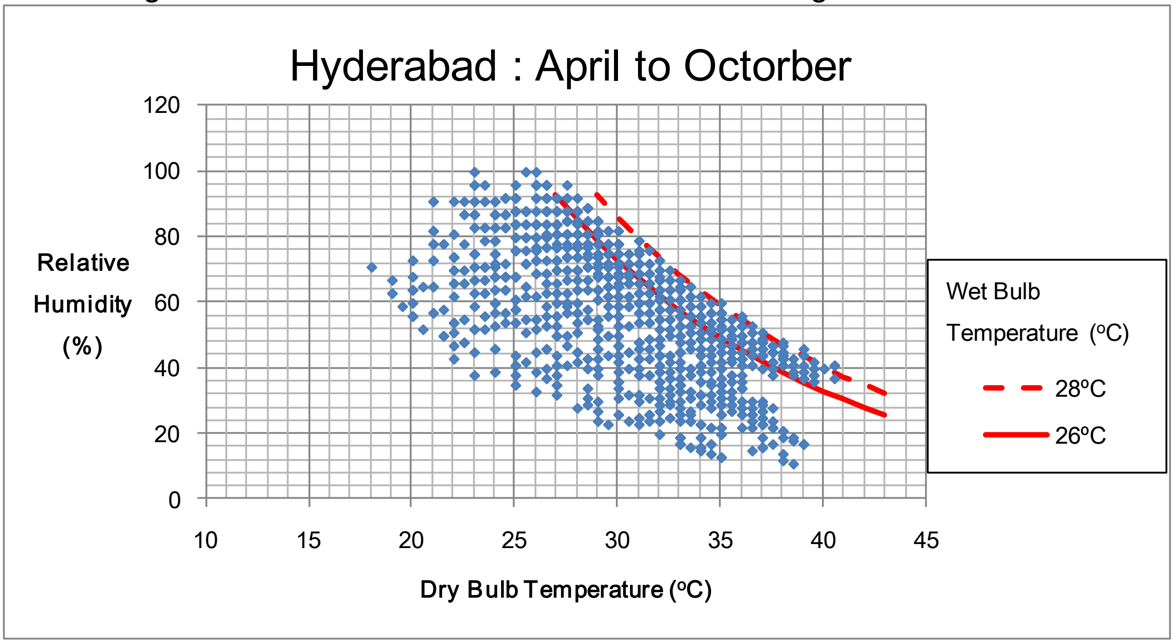
Figure 3.4-1 Chhor wet bulb temperature in summer season

(2) Wet Bulb Temperature in Indus River Area

It is noticed in Figure 3.4-2, when dry bulb temperature is high, relative humidity is low and the highest wet bulb temperature is about 28 °C.

According to the above characteristics design, wet bulb temperature is selected of 26 °C for the parameter to control the temperature of cooling water..

Meteorological Data in accordance with condenser cooling



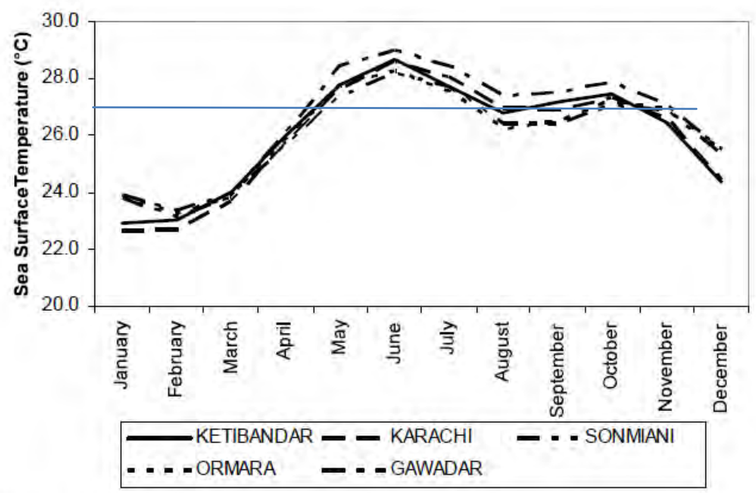
Source: JICA Survey Team

Figure 3.4-2 Hyderabad wet bulb temperature in summer season

(3) Sea surface temperature in Karachi Port Area

In case of costal area, sea water is directly used for the condenser cooling water.

Sea water temperature of about 27 °C is selected as the design temperature.



Mean monthly Sea Surface Temperature (SST) in the offshore area of Pakistan Coast.

Source: Journal of Basic and Applied Sciences Vol. 4, No. 2, 67-72, 2008

Figure 3.4-3 Sea surface water temperature

3 - 8 BASIC SPECIFICATION OF THE PLANTS

Basic specification of the plants

Area	Thar Area	Indus River Area			Karachi Port Area		
Main Coal	Thar Lignite	Thar Lignite	Sub-Bituminous 80% +Thar Lignite 20%	Bituminous coal 80% + Thar Lignite 20%	Thar Lignite	Sub-Bituminous 80% +Thar Lignite 20%	Bituminous coal 80% + Thar Lignite 20%
Plant system	Super Critical steam cycle	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left
Boiler	Lignite coal fired balanced draft boiler	same as on the left	Sub-Bituminous coal fired balanced draft boiler	Bituminous coal fired balanced draft boiler	Lignite coal fired balanced draft boiler	Sub-Bituminous coal fired balanced draft boiler	Bituminous coal fired balanced draft boiler
Turbine	Single reheat condensing, tandem-compound turbine	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left
Generator	Totally enclosed, three phase, 50 Hz, synchronous machine	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left
Boiler Feed Pump	Turbine driven BFPs (50% x 2)	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left	same as on the left
Cooling Tower	Natural draft type cooling tower	same as on the left	same as on the left	same as on the left	NA (Sea Water cooling)	NA (Sea Water cooling)	NA (Sea Water cooling)
Plant Output (Net)	600MW	600MW	600MW	600MW	600MW	600MW	600MW
Plant Efficiency (Net)(HHV)	35.0%	35.0%	36.4%	36.9%	35.7%	37.1%	37.6%
Plant Efficiency (Gross)(HHV)	37.7%	37.7%	38.9%	39.4%	38.4%	39.6%	40.2%
Plant Efficiency (Gross)(LHV)	44.0%	44.1%	42.3%	42.3%	44.9%	43.1%	43.1%
Main Steam Pressure	24.1MPa	24.1MPa	24.1MPa	24.1MPa	24.1MPa	24.1MPa	24.1MPa
Main Steam Temperature	593°C	593°C	593°C	593°C	593°C	593°C	593°C
Hot Reheat Temperature	593°C	593°C	593°C	593°C	593°C	593°C	593°C
Condenser Vacuum	0.112bar	0.111bar	0.111bar	0.111bar	0.07bar	0.07bar	0.07bar

3 - 9 AMOUNT OF WATER SUPPLY

Amount of Water Supply Required

Area	Thar Area	Indus River Area	Karachi Port Area
Cooling tower	1,700m^3/h	1,700m3/h	NA
FGD	150 m^3/h	150 m3/h	150 m^3/h
Plant make up	50m^3/h	50m3/h	50m^3/h
Miscellaneous	60m^3/h	60m3/h	60m^3/h
Total	1,960m^3/h	1,960m^3/h	260m^3/h

3 – 10 CONSIDERATION ON THE SITE SELECTION IN SOUTHEASTERN AND WESTERN KARACHI

Consideration on Site Selection in Southeastern and Western Area of Karachi

This study was conducted for obtaining further information especially in southeastern and western areas of Karachi in association with a local consultant (Hagler Bailly Pakistan) after the determination of the candidate site at Lakhra.

1. General

(1) JICA Guidelines for Environmental and Social Considerations (April 2010)

JICA Guidelines regulates the activities in protected areas as follows;

"Projects must, in principle, be undertaken outside of protected areas that are specifically designated by laws or ordinances for the conservation of nature or cultural heritage (excluding projects whose primary objectives are to promote the protection or restoration of such areas). Projects are also not to impose significant adverse impacts on designated conservation areas." (Compliance with Laws, Standards, and Plans)

"*Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests.*" (Ecosystem and Biota)

(2) Legislation

According to Sindh Wildlife Protection Ordinance 1972, the following clauses are designated on the activities within wildlife sanctuary.

No person shall-

(i) enter or reside,

(ii) cultivate any land,

(iii) damage or destroy any vegetation,

(iv) hunt, kill or capture any wild animal or fire any gun or other firearm within three miles of the boundaries or,

(v) introduce any exotic species of animal or plant,

(vi) introduce any domestic animal or allow it to stray,

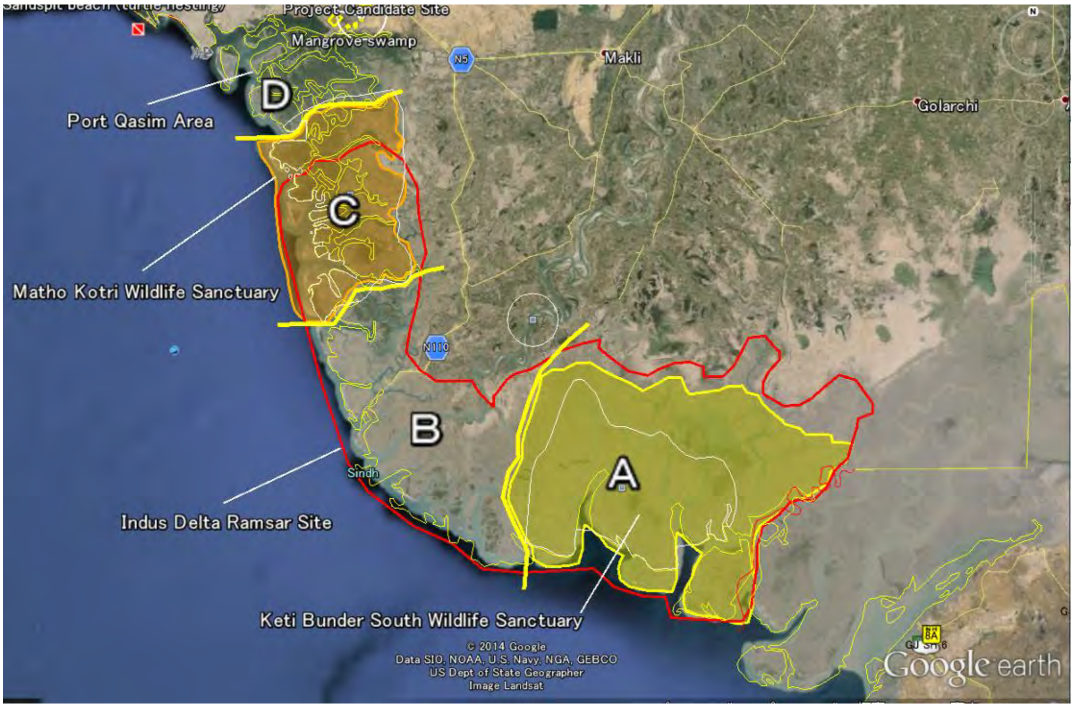
(vii) cause any fire, or

(viii) pollute water, in a wildlife sanctuary: Provided that Government may for scientific purposes or for aesthetic enjoyment or betterment of scenery authorize the doing of the aforementioned acts.

2. Southeastern Area of Karachi

(1) Outline

As candidate sites for the Project in Pakistan, JST has made investigation on the southeastern area of Karachi. The area is demarcated into four parts (A, B, C and D) according to their protected conditions such as wildlife sanctuary (Figure 1). The Indus Delta Ramsar site covers the areas of A, B and C.



Source: JICA Survey Team (Google earth)

Figure 1: Eastern Area of Karachi

(2) Area A, B and C

a. Protected Area and Ecosystem

As shown in Figure 1, Keti Bunder South Wildlife Sanctuary (Area A) and Matho Kotri Wildlife Sanctuary (Area C) exist in this area. In those areas, any activities mentioned in Section 1 (1) are prohibited. Those areas are also included in the Indus Delta Ramsar site, where sustain a huge variety of organisms such as Ginant snakehead (Channa marulius), Indus baril (Barilius modestus), Indus garua (Clupisoma naziri) and Rita catfish (Rita rita), and a number of migrant birds come over every year. Besides, Indus River Dolphin (Platanista gangetica) listed in IUCN Red List as endangered species is living there.

Regarding development actions in registered wetlands under the Ramsar Convention, there is no designation in the national regulations. Project implementer should apply to the Ramsar Secretariat and prepare an EIA for the project. If Sindh EPA approves the EIA, the project can be commissioned.

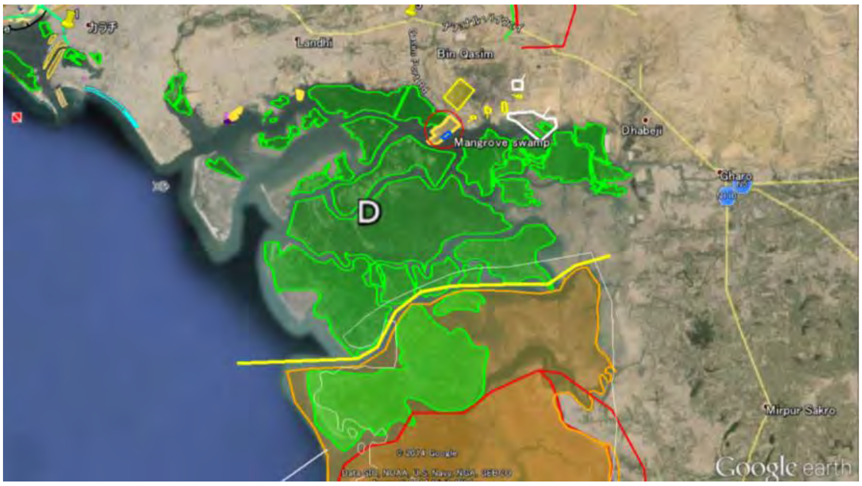
b. Evaluation

From international point of view, this Project should not be implemented in protected area due to its environmental impact on natural resources even if development actions are allowed in registered wetland area under the Ramsar Convention.

(3) Area D

a. Protected Area and Ecosystem

This area does not belong to any protected area. As shown in Figure 2, however, large mangrove swamps inhabit in Port Qasim area, therefore the area plays a very important role for aquatic organisms.



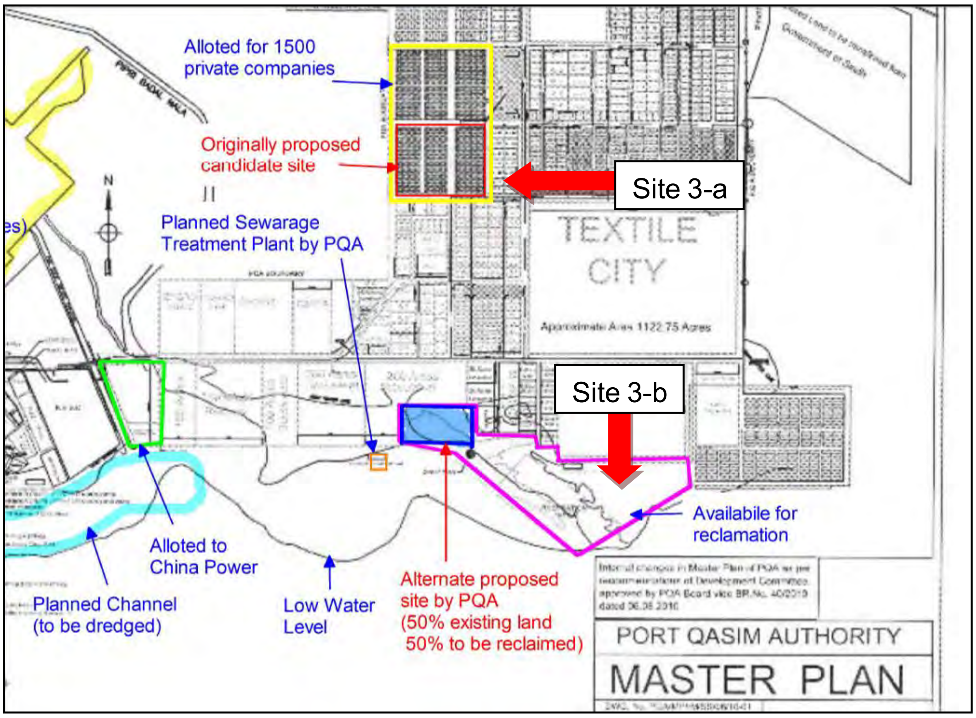
Source: JICA Survey Team

Figure 2: Mangrove Distribution Map

b. Candidate Site

This area has high density of population due to the vicinity of Karachi city. So Port Qasim Industrial Park (PQIP) is the most preferable for the Project in the area.

According to site investigation, two locations were selected in the PQIB (Figure 2).



Source: Master Plan, Port Qasim Authority

Figure 3: Candidate sites in Area D

Regarding the cooling system, as the sea water circulation system generates thermal discharge to the sea which causes adverse impact on the benthic organisms and mangroves, dry or wet-type cooling system shall be adopted.
The comparison result of these sites is shown in Table 1.

Table 1: Comparison of Candidate Sites

	Site 3-a	Site 3-b
Land owner (Land cost)	Private companies (Rs. 30 mil/acre)	PQA (Rs. 5 mil/acre)
Distance from sea	2.5 km	0 km
Land reclamation	N/A	Approx. 100 ha should be reclaimed. (Cost: Rs. 3,000 mil)
Vegetation	Shrubs and grasses	Shrubs, grasses and mangroves
Environmental impact	Effluent from the power plant flows to the stream connecting to the sea. Livestock is bred by local people at the estuary and may drink the water.	Reclamation work requires removal of mangroves. Important habitats for aquatic organisms are disturbed temporarily.
Social impact	Local people may give some grievances on the health of their livestock.	Fishery, mainly prawn and shrimp fishing, may be affected due to the reclamation.

Source: JICA Survey Team

c. Evaluation

[Site 3-a] needs high cost for the land acquisition and may have some adverse impacts on the health of livestock even if the effluent is treated to meet the NEQS for effluents.
[Site 3-b] needs reclamation works affects the ecosystem in the sea. According to the JICA Guidelines, mangrove wetland is defined as one of the sensitive areas. The following description in the guideline should be taken into account for site selection as well.

Ecosystem and Biota

1. Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests.

(4) Conclusion and Suggestion

From environmental and social point of view, [Site 3-a] is relatively appropriate place in the Eastern Karachi compared with [Site 3-b] due to its potential adverse impact on the ecosystems including mangrove wetland. [Site 3-a], however, should be further evaluated from economic point of view by comparing with the other candidate sites in Pakistan.

3. Western Area of Karachi

(1) Outline

JST has made site investigation on the western area of Karachi in the end of May, 2014, where is bordered by Hub River which forms the provincial boundary between the province of Sindh and the province of Balochistan.

(2) Land Use

The current land use is shown in Figure 3. In terms of natural features, two types of areas have been identified:

- Hills and rocky outcrop
- Hub River bed and associated wetland.

The land use has been categorized as follows:

a. Fruit orchards mainly irrigated by transporting water from Hub River
b. Rain-fed agricultural farms
c. Developed residential and commercial areas
d. Planned residential and commercial areas
e. Poultry farms
f. Small check dams and water ponds
g. Public beaches
h. Industrial areas including warehouses
i. Military bases and training areas.

(3) Features of the Area

a. Water Resources

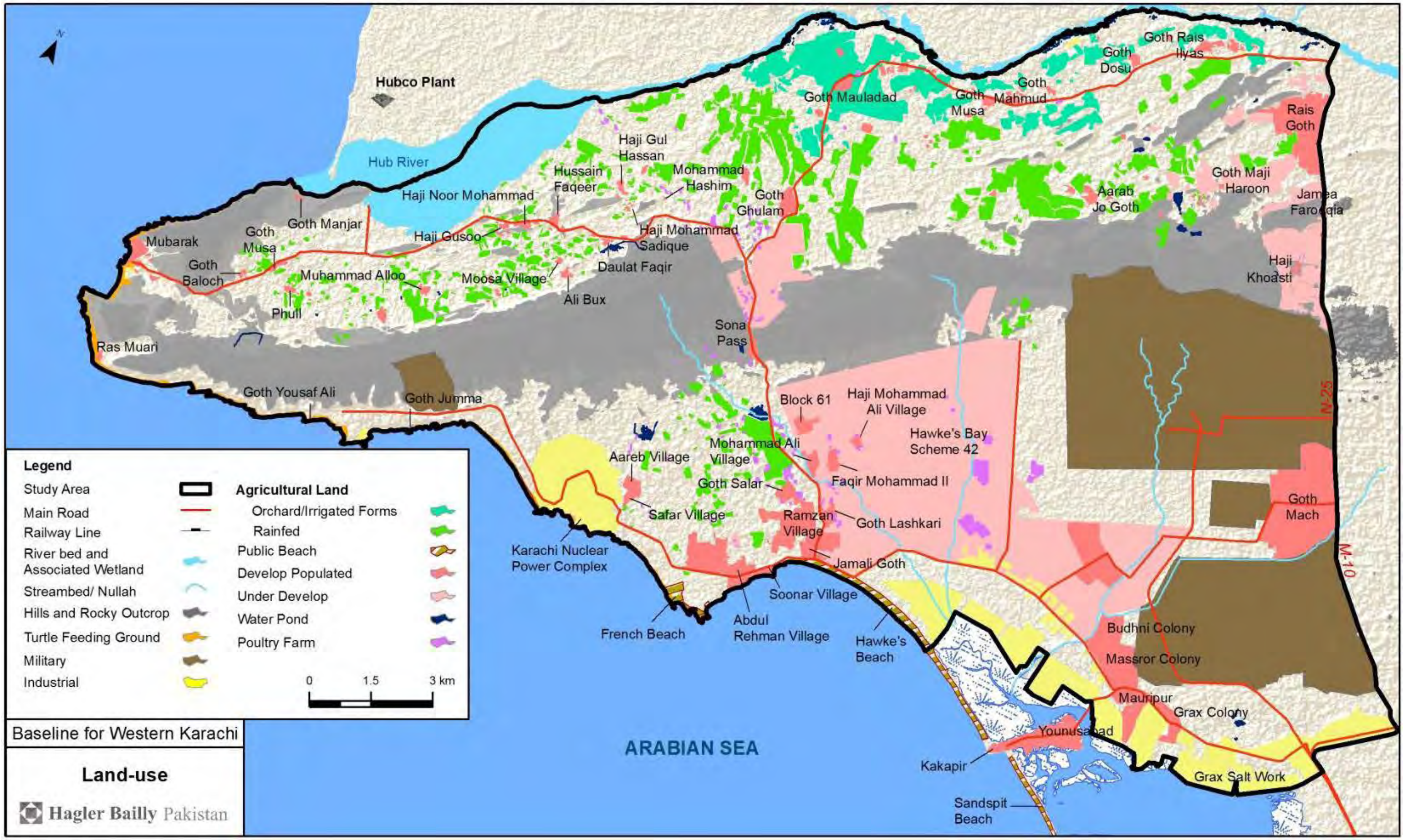
A very important factor in selection of the site will be availability of cooling water and process water. Because of the large distance and other factors, once-through cooling system based on sea water will not be possible. Similarly, circulating water cooling system based on freshwater is also not possible as groundwater and surface water resources in the Study Area are limited. Therefore, only air-cooled power plants appear feasible in the Study Area. For process water, two options may be explored. First is transporting water from sea through pipelines. The water requires desalination and treatment for use in the power plant. The second possible option is drilling of deep well on the site to obtain groundwater. The evidence suggests that the water is saline and requires desalination and treatment.

b. Hub River

The Karachi basin is drained by Malir, Lyari, and Hub Rivers. Malir and Lyari Rivers are non-perennial rivers that drain the central and eastern sides of Karachi. Hub River borders the westerns side of Karachi and drains the western and north-western parts. Hub River that flows about 30 km west of Karachi falls into the Arabian Sea near Cape Monze. It is a semi-perennial river in which water is always found in pools. The river is also source of recharge of some aquifers found in the northwest parts of Karachi.[1]

---

[1] A. Mashiatullah, R. M. Qureshi, T. Javed . *Isotope Hydrochemical Evaluation of Groundwater Salinity in Coastal Karachi, Pakistan*, pecongress.org.pk/images/upload/books/Isotop%20hydrochemical.pdf



Source: Hagler Bailly Pakistan

Figure 4: Land Use

c. Turtle

The Green Turtle (*Chelonia mydas*) and Olive Ridley (*Leidochelys*) are found on the shore of the Karachi coast, on the Hawkes bay and Sands pit, along a stretch of 35 km. Both are endangered species (Firdous, 1988). Peak nesting at Karachi is during the period between September to November. Some areas on the Gadani coast appear to be suitable for nesting where occasionally green turtles were seen in the past. The coastal areas are considered feeding ground for the turtles. The main breeding areas are located either near Cape Monze and near Sandspit. Hatcheries of the turtles are also established at Sandspit by the Sindh Wildlife Department.

(4) Selection Criteria

The criteria can be divided into two categories: the *threshold criteria* and the *distance criteria*. The threshold criteria are set mostly by external factors and result in excluding certain areas from consideration. The distance criteria include factors where it is desirable to maximize or minimize distance from certain features. The proposed set of Threshold and Distance criteria are shown in Table 2 and 3.

Table 2: Threshold Criteria

Criteria	*Explanation*
Avoid settlements, commercial, industrial, and military areas	Most of these lands are either not available or where available relocation has high economic and social costs
Avoid hills and rocky areas	High construction cost and risk of erosion
Avoid prime agricultural lands	Changing land use from prime agricultural lands (including orchards) to industrial purpose is not environmentally good practice and can have high social and economic cost
Avoid ecologically sensitive areas	Environmental impacts and legal restrictions
Avoid infrastructures	Relocation of infrastructure (power lines, small dams, roads) is costly and may not be possible

Table 3: Distance Criteria

Features	*Value*	*Explanation*
Coastal Area	Maximum distance	Visual impacts, erosion
Transmission line	Minimum distance	Interconnection
Access	Close to highway	Transportation
Water	Access to source of water for cooling water and other purposes	-
Water	Access to sea for discharge	-
Community	Maximum distance to settlements	Minimize environmental impacts

(5) Selection of Potential Sites

The threshold criteria are applied to the Study Area. It results in excluding more than 60% of the area from consideration. The remaining area is considered permissible zone and is shown in Figure 4.

Within the permissible zone of the Study Area potential sites were identified. In selecting these sites the following were taken into consideration:

- ✓ Site should be close to road but should not block or result in diversion of any sealed or unsealed road.
- ✓ To the extent possible, the site should be of regular shape (rectangle or near rectangle)
- ✓ Site should be large enough (about 200 hectares) to provide flexibility during layout of plant facilities
- ✓ Acquisition of agricultural land and poultry farm shall be minimized
- ✓ Site should be close to transmission lines.

Application of these criteria resulted in identification of three potential sites as shown in Figure 4. Two of these are located to the west of the Study Area, whereas the third is near the center.

(6) Discussions and Conclusions

Comparison of each candidate site is shown in Table 4.

Table 4: Comparison of Selected Site

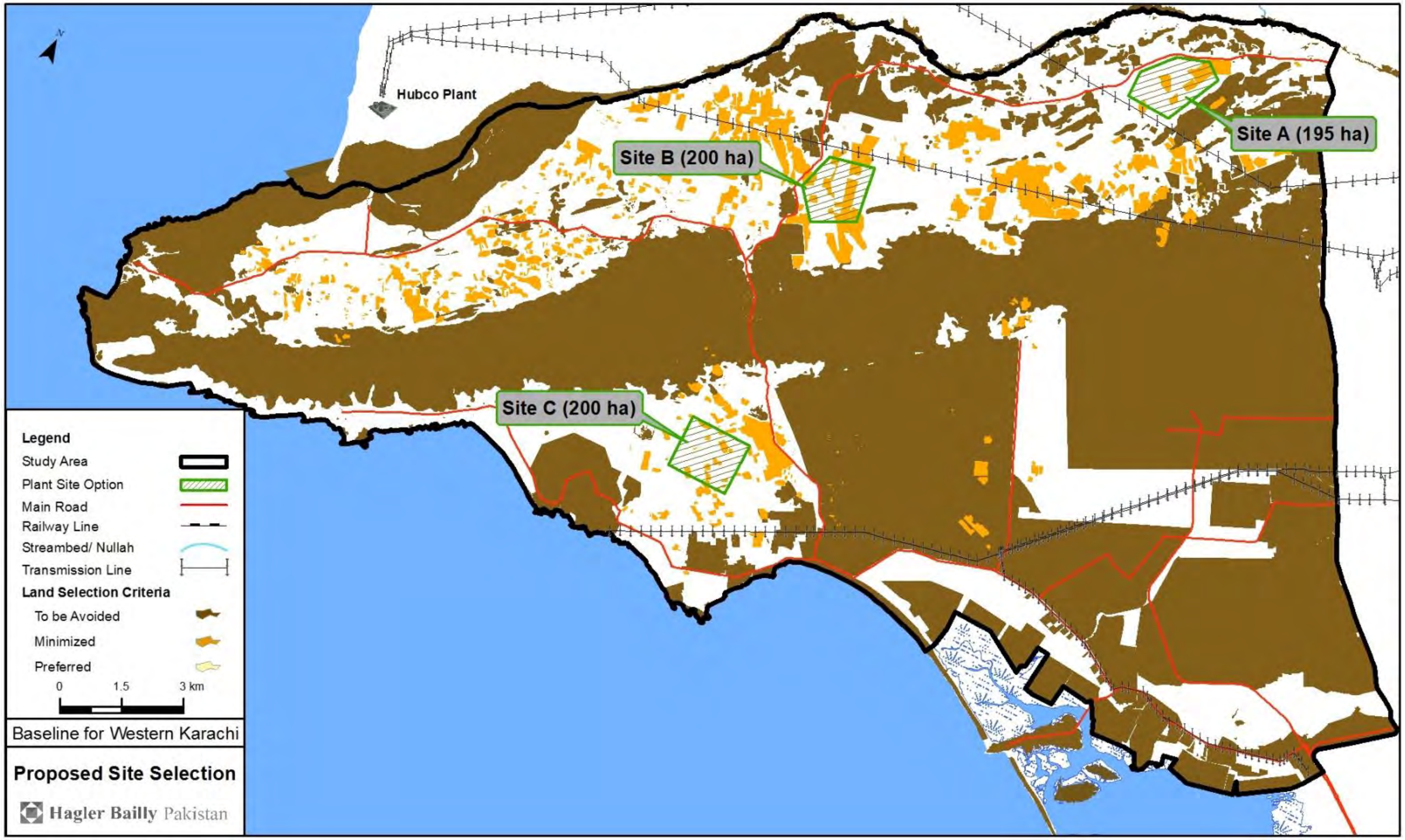
Feature	*Site A*	*Site B*	*Site C*
Distance Criteria			
Distance to shoreline	14 km	9 km	3 km
Distance to transmission Line	500 m (500 kV line)	500 m (500 kV line)	8 km (500 kV line)
Distance to highway	4 km	15 km	19 km
Distance to sea for water sourcing	23 km	14 km	17 km
Distance to wastewater disposal point	17 km (Hub River)	8 km (Hub River)	11 km (Hub River)
Nearest Settlement	Less than 1 km	Less than 1 km	Less than 1 km
Other Considerations			
Land Use: Agricultural land within site	40 ha (Rain-fed agriculture)	68 ha (Rain-fed agriculture)	26 ha (Rain-fed agriculture)
Land Use: Poultry farms land within site	0 ha	0 ha	0.1 ha
Topological	Flat sandy land	Flat sandy land	Relatively flat sandy land Stormwater flows from north to south
Vegetation	Shrub	Shrub	Shrub
Land acquisition	N/A	N/A	Poultry farmer's land
Resettlement	N/A	N/A	N/A
Land owner	N/A	N/A	N/A

Site A: This site has difficulties in securing water and effluent disposal point.

Site B: This site has difficulties in securing water and effluent disposal point.

Site C: This site has difficulties in securing water and effluent disposal point. Besides, resettlement of poultries would be required.

The western area of Karachi has difficulties in securing water for the power plant and effluent disposal point. The water resource is a critical condition for the Project.
As a result, there is no appropriate site for the Project in western Karachi.



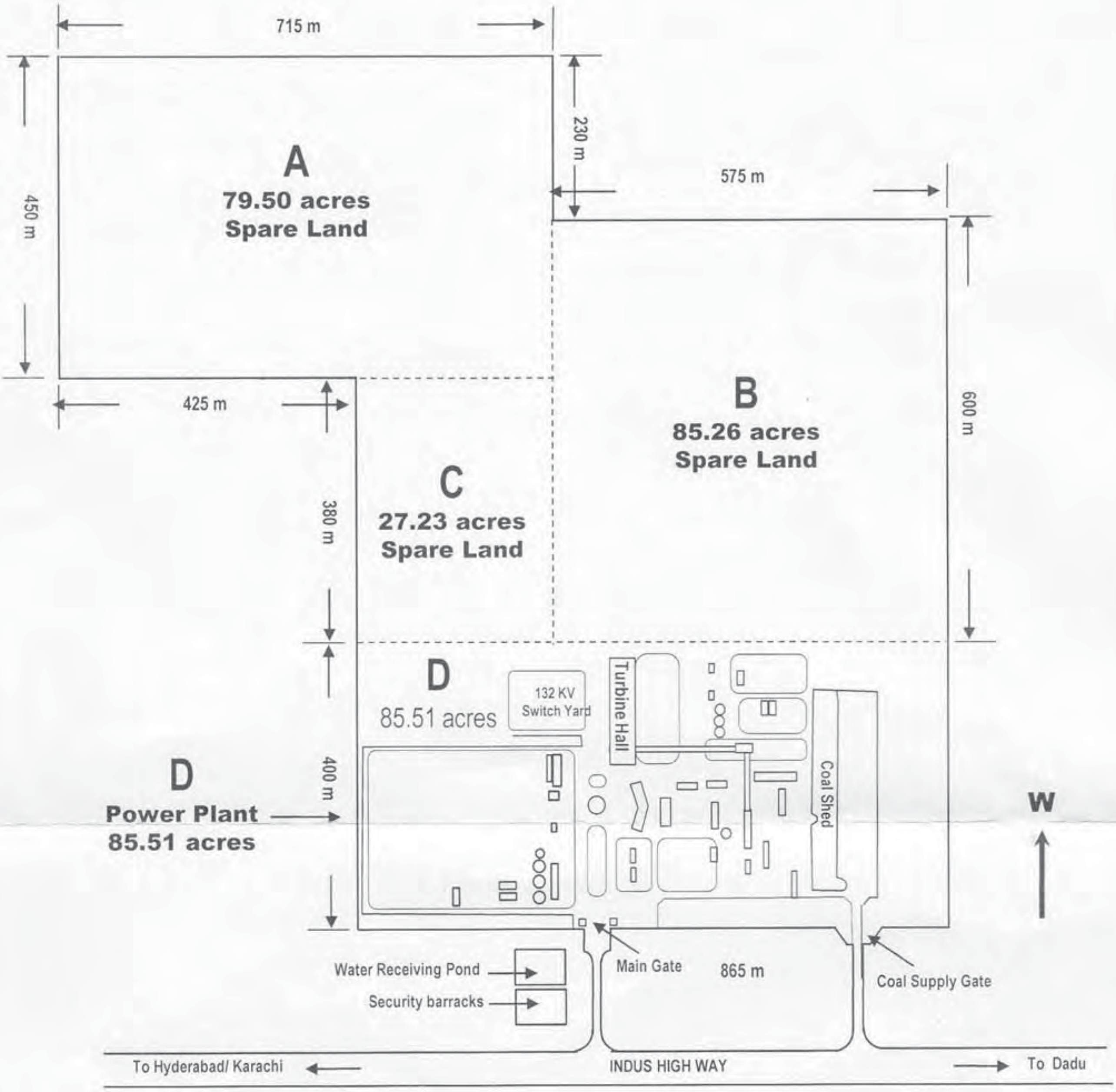
Source: Hagler Bailly Pakistan

Figure 5: Selected Sites

4 - 1 DETAIL OF POWER PLANT LAND

Appendix 4-1

LAKHRA POWER GENERATION CO. LTD
LAYOUT PLAN OF LAKHRA POWER PLANT



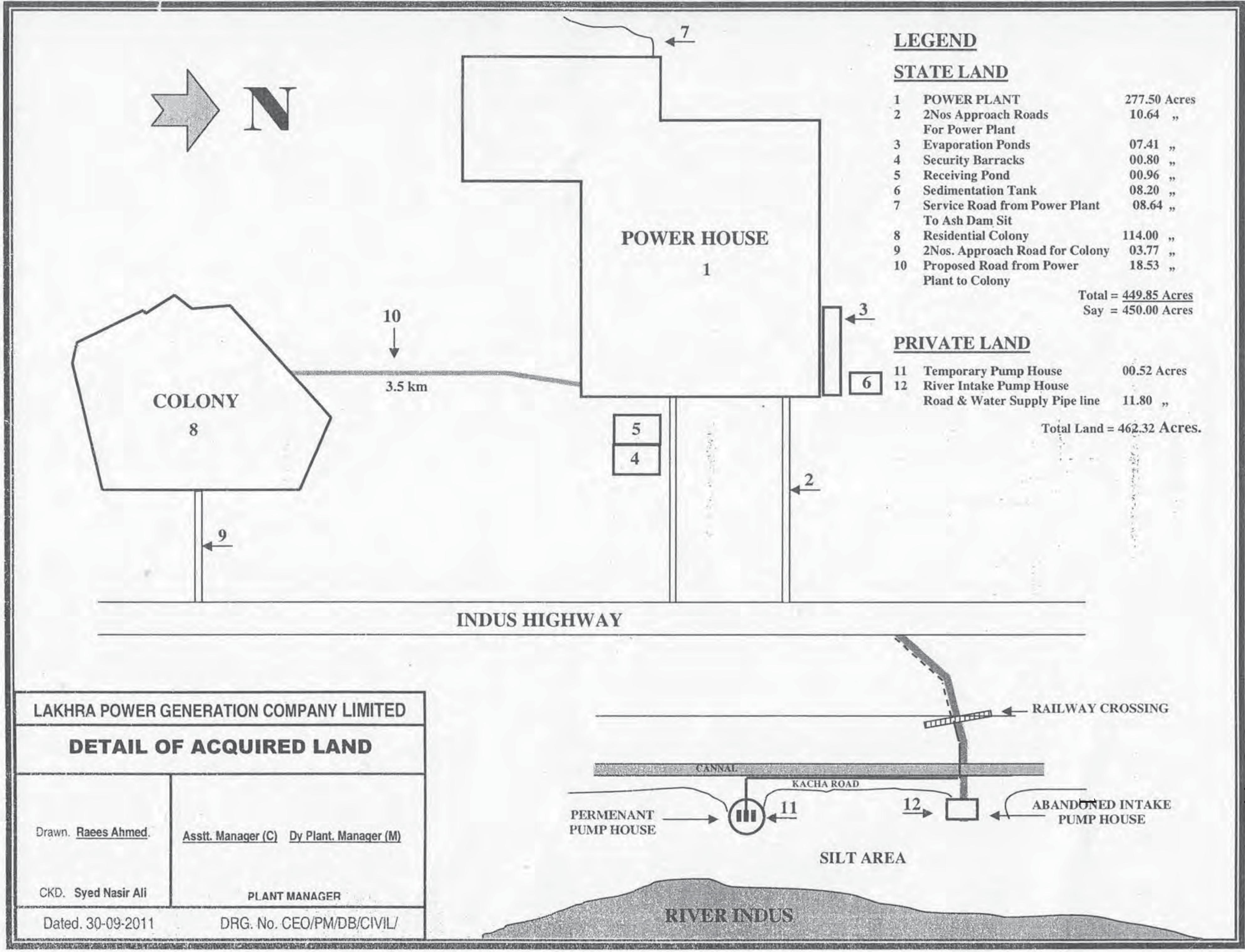
DETAIL OF POWER PLANT LAND

	A =	79.50 acres
	B =	85.26 acres
	C =	27.23 acres
Total Spare Land		191.99 acres
Power Plant	D =	85. 51acres
Total Power Plant Land	=	277.50 acres

Racas

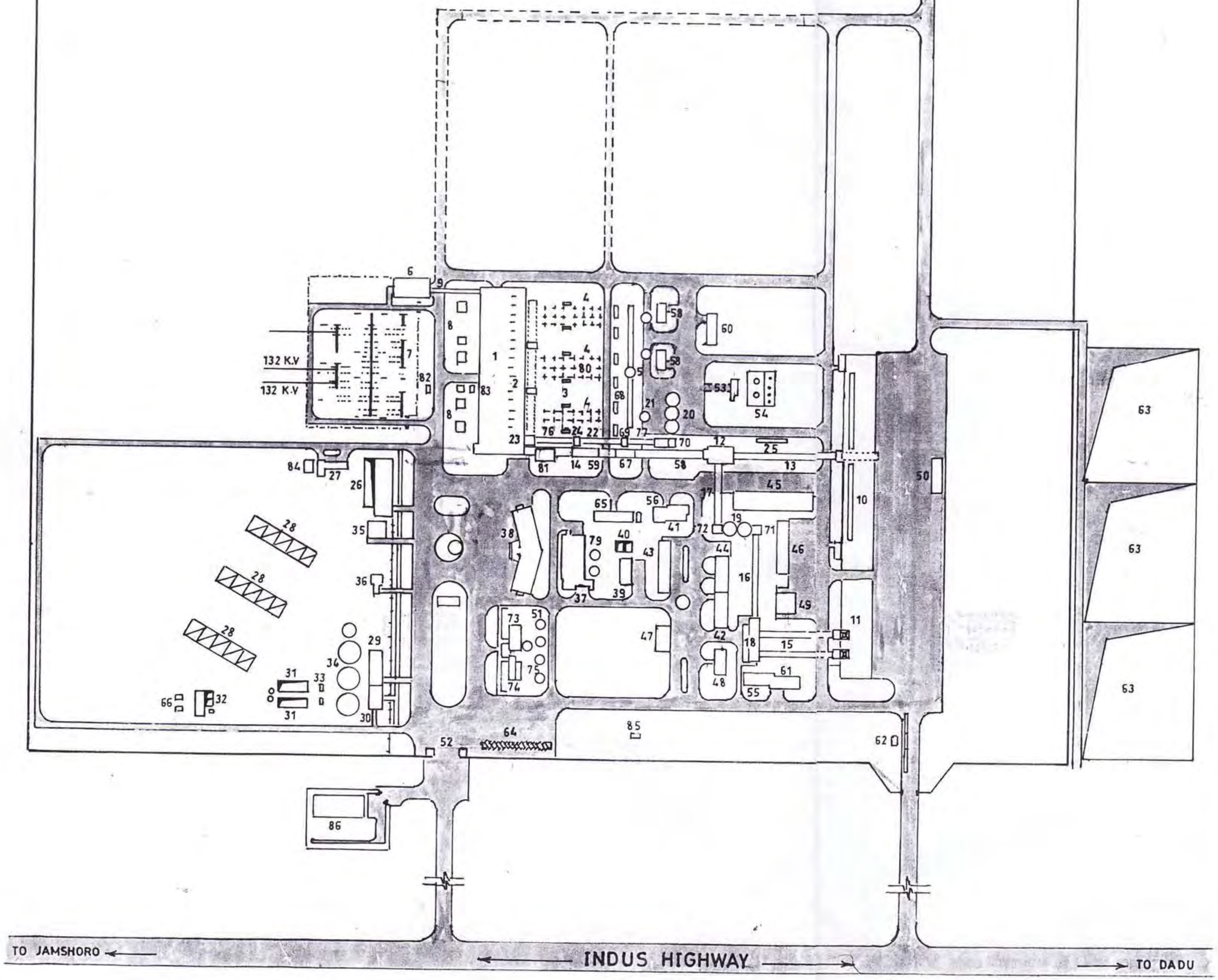
4 - 2 DETAIL OF ACQUIRED LAND

Appendix4-2



N
LEGEND
STATE LAND
1 POWER PLANT 277.50 Acres
2 2Nos Approach Roads For Power Plant 10.64 „
3 Evaporation Ponds 07.41 „
4 Security Barracks 00.80 „
5 Receiving Pond 00.96 „
6 Sedimentation Tank 08.20 „
7 Service Road from Power Plant To Ash Dam Sit 08.64 „
8 Residential Colony 114.00 „
9 2Nos. Approach Road for Colony 03.77 „
10 Proposed Road from Power Plant to Colony 18.53 „
Total = 449.85 Acres
Say = 450.00 Acres
PRIVATE LAND
11 Temporary Pump House 00.52 Acres
12 River Intake Pump House Road & Water Supply Pipe line 11.80 „
Total Land = 462.32 Acres.
POWER HOUSE
1
COLONY
8
10
3.5 km
INDUS HIGHWAY
RAILWAY CROSSING
CANNAL
KACHA ROAD
PERMENANT PUMP HOUSE
ABANDONED INTAKE PUMP HOUSE
SILT AREA
RIVER INDUS
LAKHRA POWER GENERATION COMPANY LIMITED
DETAIL OF ACQUIRED LAND
Drawn. Raees Ahmed.
Asstt. Manager (C)
Dy Plant. Manager (M)
CKD. Syed Nasir Ali
PLANT MANAGER
Dated. 30-09-2011
DRG. No. CEO/PM/DB/CIVIL/

4 - 3 EXISTING PLANT LAYOUT PLAN



LIST OF BUILDINGS/STRUCTURES

Nö	BUILDINGS/STRUCTURES	Nö	BUILDINGS/STRUCTURES
01	TURBINE HALL	44	WELDING AND FORGING SHOP
02	DEAERATOR COAL BUNKER BY	45	MATERIAL WAREHOUSE
03	BOILER	46	MATERIAL SHED
04	BAGHOUSE	47	GARAGE AND FIRE STATION
05	CHIMNEY/GAS DUCT	48	CARPENTER SHOP
06	MAIN CONTROL BUILDING	49	DANGEROUS OBJECTS STORAGE
07	132K.V SWITCH YARD	50	BULLDOZER GARAGE
08	MAIN TRANSFORMER	51	WATER TOWER
09	OVERHEAD CORRIDOR	52	GUARD AND JANITORS ROOM
10	COAL SHED	53	IGNITING OIL PUMP HOUSE
11	LIMESTONE SHED	54	IGNITING TANK
12	COAL CRUSHER HOUSE	55	BATH ROOM AND TOILET
13	COAL CONVEYER No: 2	56	PRIMING BOILER HOUSE
14	COAL CONVEYOR No: 3	57	DELETED
15	LIMESTONE CONVEYER No: 5	58	NEGATIVE PRESS: FAN ROOM
16	LIMESTONE CONVEYER No: 7	59	AIR COMPRESSOR ROOM
17	LIMESTONE CONVEYER No: 10	60	CINDER DISPOSAL C/ROOM
18	STONE CRUSHER HOUSE	61	COAL HANDLING MAINT: SHOP
19	LIMESTONE SILO	62	WEIGHBRIDG
20	SLAG SILO	63	EVAPORATING POOL
21	ASH SILO	64	GARAGES
22	SLAGE SCRAPER No: 5	65	REFRIGERATION PLANT
23	SLAGE TRANSFER TOWER No: 3	66	SEWAGE WATER TREAT: DEVICE
24	SLAGE TRANSFER TOWER No: 4	67	CINDER DISPOSAL SWITCH ROOM
25	COAL SETTLING POOL	68	INDUCED FAN FOUNDATION
26	C.W PUMP HOUSE	69	SLAGE TRANSFER TOWER No: 5
27	CHLORINE INJECTION ROOM	70	SLAGE TRANSFER TOWER No: 6
28	MECH: DRAFT COOLING TOWER	71	L/STONE TRANSFER TOWER No: 2
29	COMPREHENSIVE WATER P/HOUSE	72	L/STONE TRANSFER TOWER No: 3
30	CHEMICAL INJECTING ROOM	73	SOFT WATER TREATMENT
31	CLARIFICATION	74	INDS: W.P.H AND WATER INTAKE
32	SEWAGE WATER PUMP HOUSE	75	GLASS FIBER COOLING TOWER
33	VALVELESS FILTERING BASIN	76	SLAGE SCRAPER No: 4
34	PURIFIED WATER BASIN	77	SLAGE SCRAPER No: 6
35	C.W SWITCH ROOM	78	DELETED
36	HYDROGEN STATION	79	DEMINERALIZED WATER TANK
37	CHEMICAL WATER TREAT: PLANT	80	CONTROL ROOM OF BAGHOUSE
38	OFFICE BUILDING	81	DIESEL GENERATOR ROOM
39	ACID AND BASE STORAGE	82	No:1 EMERGENCY OIL TANK
40	NEUTRALIZING POOL	83	No:2 EMERGENCY OIL TANK
41	COAL HANDLING SWITCH ROOM	84	ACID INJECTING ROOM OF W.C
42	ELECT: MAINTENANCE SHOP	85	GAS REGULATION STATION
43	MECHINE SHOP	86	PRE SEDIMENTATION POND

PAKISTAN
WATER AND POWER DEVELOPMENT AUTHORITY

150M.W LAKHRA F.B.C POWER PLANT Khanc

GEN: LAYOUT PLAN

DRAWN: RAEES AHMED | JUNIOR ENGINEER (Civil)

CHECKED | RESIDENT ENGINEER

DATE. MAY. 1995 | DRAWING Nö R.E/LOP/C/PS.0

Appendix 4-3

5 - 1 SPONTANEOUS COMBUSTION PHENOMENA OF COAL

Spontaneous Combustion Phenomena of Coal

1. Spontaneous combustion

In general, coal reserves don't get combustion in the ground due to lack of enough supplied oxygen. The oxidation reaction of coal occurs by exposing to the air, and then the coal emits exothermic heat.

$$\text{Coal} + O_2 \Rightarrow CO + H_2O + 2{,}500 \text{ cal/g (coal)}$$

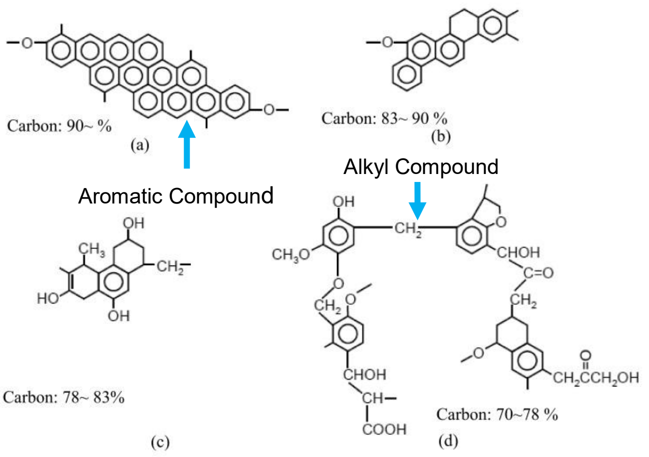
The heating value of the oxidation per molecule carbon is 2,500 cal/g. This oxidation occurs even at the room temperature. This chemical reaction is so-called spontaneous combustion of coal.

Spontaneous combustion of coal occurs in long term of several weeks during storage. It rarely occurs during transportation from coal mines to power plants which takes a few weeks.

Preventing storage coal from spontaneous combustion, the period of coal storage is managed as less than two months in general. During storage, the temperature of coal is normally measured at regular intervals of distance and depth, and is monitored constantly. With the observation of temperature rising trend (70^{o}C to 80^{o}C or more), measures such as Diffusion of high-temperature area, watering, and re-formation of the coal pile, are taken to diffuse and take away heat from the relevant area to eliminate the spontaneous ignition.

2. The difference of coal molecular structure

The coal is classified as anthracite, bituminous sub-bituminous, lignite, and so on by the difference in calorific value per unit weight. Coal molecular structures are shown in Figure 1.



Legend

(a) anthracite
(b) bituminous
(c) sub-bituminous
(d) lignite

Hexagonal shape is shown aromatic compound.

-CH_2-, -CHOH- are shown Alkyl compound

Source: JICA Survey Team

Figure 1 Molecular Structure of Coals

It is generally said that the lignite coal easily gets self-ignition compared with bituminous and sub-bituminous coal due to more contacted oxygen caused in accordance with its molecular structure than others. The phenomenon is rather exothermic reaction of coal than "combustion". White smoke is generally observed over 100 ^{o}C. The self-ignition point is more than 300 ^{o}C at least.

The spontaneous combustion is not meant to be accompanied by a rapid temperature rise of coal in a short time. Therefore, the phenomenon is to be prevented and controlled with adequate handling as below:

1. Sprinkling to avoid heat accumulation, covering of the pile with Tarpaulin, avoid storing/loading fine particles.

2. To measure coal pile temperature and to keep it under 80 ^{o}C.

3. In the case coal piles partially excess 80 ^{o}C, heating part should be blended and stirred with lower temperature part.

In addition, during transportation of coal, covering coal with sheets and pressing together are also the measure to prevent from self ignition.