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Performance of Oman Transmission System with the 400kV Gulf Cooperation Council Electricity Interconnection

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PERFORMANCE OF OMAN TRANSMISSION SYSTEM WITH THE 400KV GULF COOPERATION COUNCIL ELECTRICITY INTERCONNECTION

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ABSTRACT

The paper describes the static and dynamic performances of the main transmission system of Oman with the 400kV Gulf Cooperation Council (GCC) electricity interconnection between Oman and Abu Dhabi. A detailed model of the transmission system of Oman is obtained to simulate the steady-state and dynamic system performances using the DIgSILENT software. The model includes simulation of the generating units at power plants with their turbines, speed governors, exciters and voltage regulators. The UAE system is represented by an external source. Simulation results are presented to show the feasibility of successful operation with exchange of up to 400MW between Oman and UAE in either direction in 2014. The results include line and transformer loadings, voltage profiles, fault currents, and dynamic system responses to tripping the 400kV interconnector.

Index Terms— GCC interconnection, transmission system, steady-state and transient analyses.

1. INTRODUCTION

There has been a considerable interest in the development of the GCC interconnection project during the recent three decades. Details of the GCC interconnection project can be found in the GCC Interconnection Authority website [1]. Briefly, the project consists of three phases:

Phase I:
Interconnecting the GCC North Grid which includes the State of Kuwait, Kingdom of Saudi Arabia, Kingdom of Bahrain and State of Qatar.

Phase II:
Interconnecting the GCC South Grid which consists of the independent systems in the UAE and the Sultanate of Oman.

Phase III:
Interconnecting the GCC North and South Grids, thus completing the interconnection of the six Gulf States.

The objectives of the GCC interconnection are to provide economical, operational and technological benefits to the GCC countries [1]. This will improve security of supply and system reliability. The interchange of energy among the interconnected grids will reduce the total operating costs. The interconnection facilitates sharing of power generation reserves and installed capacity which can lead to optimization of investments in power generation and grid infrastructures. In addition, the interconnection can provide alternative energy sources to support individual systems during emergencies.

This paper concerns with evaluation of the steady-state and dynamic performances of Oman transmission system when interconnected to the Abu Dhabi system. The Oman-UAE interconnection will comprise a 400kV double-circuit transmission from Sewihan in the UAE to Al-Wasit (Mahadah) in Oman and a new 400/220kV grid station at Al-Wasit which will be connected to the existing 220/132 kV grid station at Al-Wasit.

A detailed model of the transmission system of Oman has been developed [2] to simulate the steady-state and dynamic system performances using the DIgSILENT software [3]. The UAE system is represented by an external source. Load flow, short-circuit and dynamic analyses are presented to show the feasibility of successful operation with exchange of up to 400MW between Oman and UAE in either direction in 2014.

Section 2 describes the transmission system of Oman, Section 3 presents the simulation results, and Section 4 summarizes the main conclusions.

2. SYSTEM DESCRIPTION

The existing transmission system extends across the whole of northern Oman and interconnects bulk consumers and generators of electricity located in the Governorate of Muscat and in the regions of Batinah, Dhahirah, Dakhliyah and Sharquiya [4].

The main transmission system is supplied with electricity generated from eight gas-based power stations located at Ghubrah (482MW), Rusail (684MW), Wadi Al-Jizzi (290MW), Manah (279MW), Al-Kamil (282MW), Barka AES (434MW), Barka SMN (683MW) and Sohar (590MW) [5]. In addition, the transmission system may be supplied from direct customers such as Sohar Aluminium Company and Petroleum Development of Oman (PDO). Currently, the transmission system of Oman is interconnected at 220 kV from Al-Wasit in Mahadah with the transmission system of the UAE, but the operation has not been initiated yet.

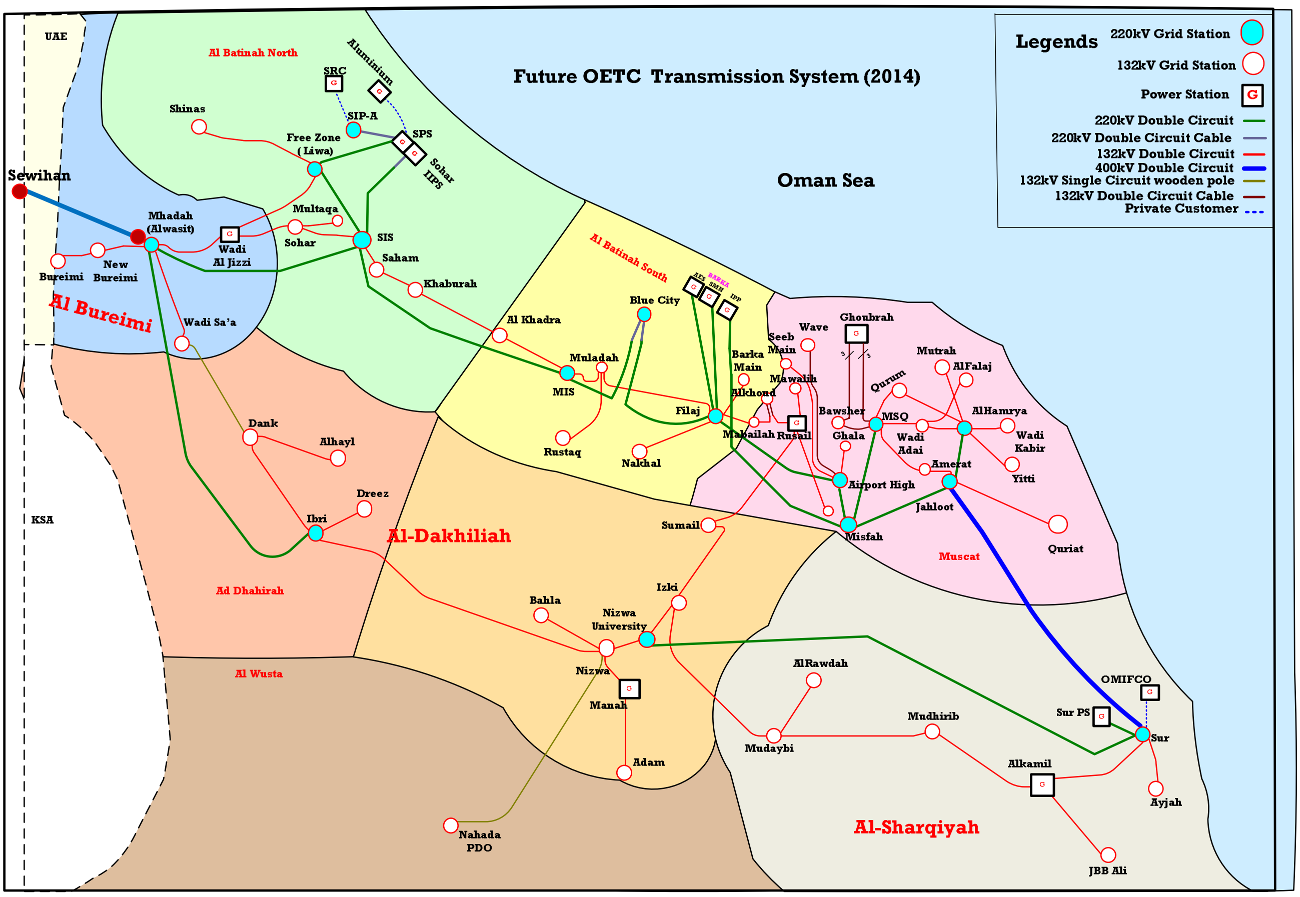

Figure 1. Oman Transmission System in 2014 (with GCC 400kV interconnection).

The bulk of the power transmitted through the main grid is fed through 220/132/33 kV and 132/33 kV grid stations to the three distribution license holders, i.e. Muscat Electricity Distribution Company, Mazoon Electricity Company, and Majan Electricity Company. In addition to the distribution companies a number of large private customers are directly connected to the transmission system. In 2010, the system gross peak demand of 3613 MW occurred at 15:00 hours on 1 June.

A major development plan is initiated in the electricity transmission system of Oman to cope with the steadily increasing demand, details can be found in [3]. Figure 1 shows a geo-schematic diagram of the system in 2014. Three new power plants will be available: 750MW at Sohar (Phase-II), 750MW at Barka (Phase-III) and 2000MW at Sur.

3. SIMULATION RESULTS

Simulation studies have been performed to evaluate the static and dynamic performances of Oman transmission system when interconnected to the UAE system. Tables 1 to 4 show samples of load flow results at summer peak demand in year 2014. Percentage of concerned line loadings are summarised in Table 1 in three cases: (i) No power exchange between the two countries, (ii) 400MW export from Oman to UAE, and (iii) 400MW import from UAE to Oman. In all cases the line loadings are well below 50%, thus maintaining the (N-1) security criterion. Table 2 shows the percentage loadings of the concerned transformers. All are well below 50%. Table 3 shows the voltage profiles in the three case studies. The busbar voltages are within the allowable range in Oman (±10%). Table 4 lists the calculated active and reactive power losses in the transmission system of Oman. The active power losses are within 2% of the total demand. This ratio is comparable with practical transmission systems.

Table 1. Line loading

Line	Loading %		
	No Exchange	Oman to UAE 400MW	UAE to Oman 400MW
Sweihan-Wasit (400kV)	NA	26.76	25.49
SIS-Wasit (220kV)	11.98	31.19	4.2
Wasit-Ibri (220kV)	5.21	2.89	9.98
Wasit-Wadi Saá (132kV)	16.77	19.62	26.93
Wasit-New Burimai (132kV)	28.56	28.94	28.35
Wadi Jizzi-Wasit (132kV)	29.39	48.35	17.81

Table 2. Transformer loading

Transformer	Loading %		
	No Exchange	Oman to UAE 400MW	UAE to Oman 400MW
Wasit (400/220kV)	NA	42.27	40.26
Wasit (220/132kV)	19.17	10.27	31.33
Wasit (132/33kV)	26.86	27.20	26.64
SIS (220/132kV)	24.51	21.84	26.69
Ibri (220/132kV)	7.95	4.41	15.24
Ibri (132/33kV)	38.76	39.95	38.36
Wadi Saá (132/33kV)	9.54	9.72	9.47
N. Burimai (132/33kV)	31.38	31.79	31.12

Table 3. Voltage profile

Busbar	Voltage (p.u.)		
	No Exchange	Oman to UAE 400MW	UAE to Oman 400MW
Wasit 400kV	NA	0.95	0.99
Wasit 220kV	0.99	0.95	0.99
Wasit 132kV	0.98	0.97	0.99
Wasit 33kV	1.00	1.00	1.01
SIS 220kV	0.99	0.98	1.00
SIS 132kV	0.98	0.97	0.99
Ibri 220kV	0.97	0.94	0.98
Ibri 132kV	0.96	0.93	0.97
Ibri 33kV	0.99	1.00	1.00
Wadi Saá 132kV	0.97	0.96	0.98
Wadi Saá 33kV	0.99	1.00	1.00
N. Burimai 132kV	0.97	0.96	0.98
N. Burimai 33kV	1.00	1.00	0.99
Wadi Jizzi 132kV	1.01	1.00	1.01

Table 4. Transmission system losses

Losses Type	Losses Value		
	No Exchange	Oman to UAE 400MW	UAE to Oman 400MW
Active Power (MW)	83.97	110.22	76.81
Reactive Power (MVAr)	1095.66	1474.69	933.07

Table 5 shows the three-phase fault levels at concerned busbars. Although, the fault current at Al-Wasit 220kV busbar increases significantly from 11.675kA to 25.878kA when the two systems are interconnected, and this value is still well below the short-circuit rating of the switchgear (40kA). In all other cases the fault currents are well below the corresponding switchgear ratings (40kA for the 220kV system and 31.5kA for the 132kV system).

Figure 2 shows the system response to tripping of the 400kV interconnector when Oman exports 400MW to the UAE at summer peak of 2014. Figure 3 shows the response to the interconnector outage when Oman imports 400MW from the UAE. In both cases the transmission system of Oman is stable and can withstand this type of sever disturbance. The sample results include rotor angles of Alkamil (alk), Manah (mnh), Barka I (brk), Sohar (sps), Wadi Jizzi (wdj), Rusail (rsl), Barka III, and Sohar II generating units. GT stands for Gas Turbine and ST stands for Steam Turbine.

Table 5. Three-phase short-circuit currents

Busbar	Ik"(kA)		
	No Exchange	Oman to UAE 400MW	UAE to Oman 400MW
Wasit 400kV	NA	14.890	14.869
Wasit 220kV	11.675	25.878	25.831
Wasit 132kV	15.448	19.666	19.670
Wasit 33kV	17.269	18.383	18.379
SIS 220kV	23.103	28.979	28.662
SIS 132kV	21.274	23.673	23.449
Ibri 220kV	6.231	7.560	7.560
Ibri 132kV	10.282	11.859	11.858
Ibri 33kV	17.120	18.128	18.127
Wadi Saá 132kV	8.408	9.496	9.494
Wadi Saá 33kV	14.049	14.765	14.764
N. Burimai 132kV	10.123	11.793	11.786
N. Burimai 33kV	16.533	17.513	17.510
Wadi Jizzi 132kV	23.895	26.821	26.752

4. CONCLUSIONS

The paper has shown that successful operation can be achieved when Oman and UAE are interconnected through the GCC 400kV system. The static and dynamic performances of the transmission system of Oman have been evaluated by simulation studies. The results have shown that line and transformer loadings are well below 50%, thus satisfying the (N-1) security criterion. The voltage levels at all HV busbars are within the allowable range in Oman. The fault currents at all busbars are well below the corresponding switchgear ratings. The dynamic results have shown that the system is stable even with severe outages.

5. REFERENCES

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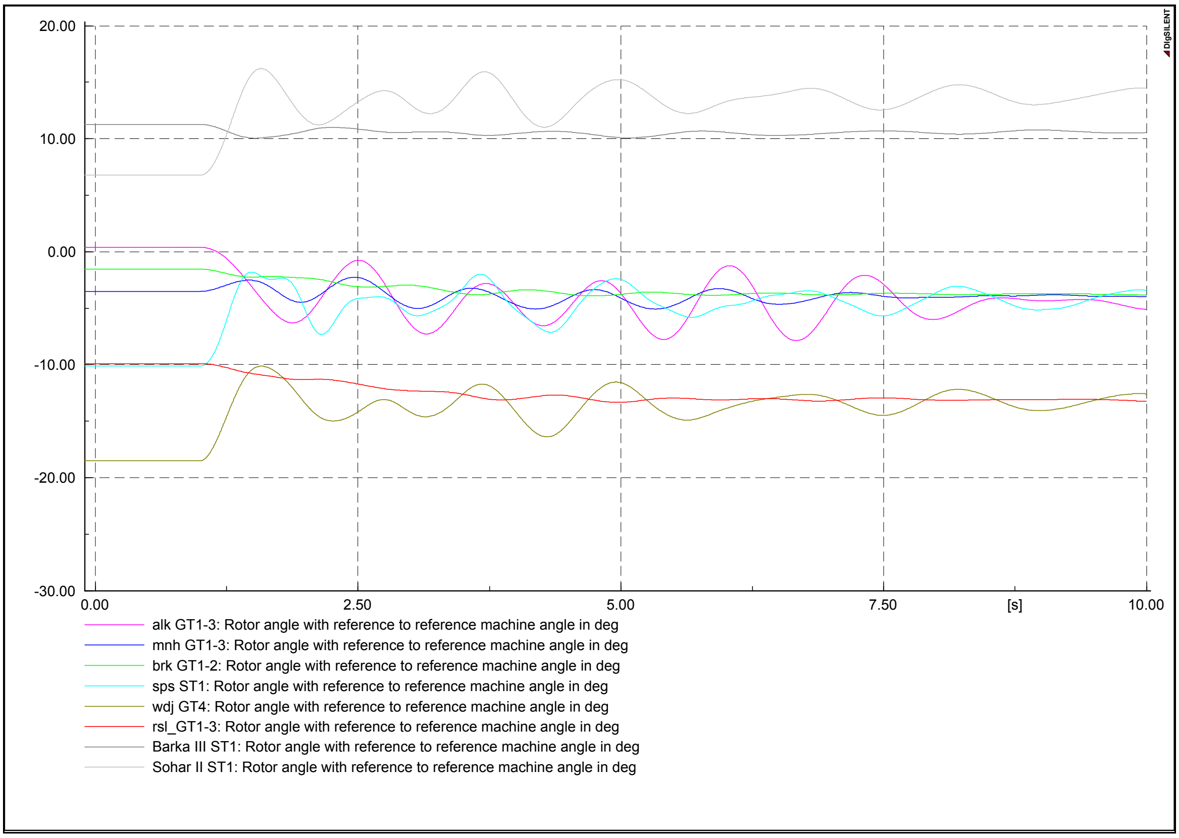

Figure 2. Rotor angle response to interconnection outage (Oman exports 400MW to UAE).

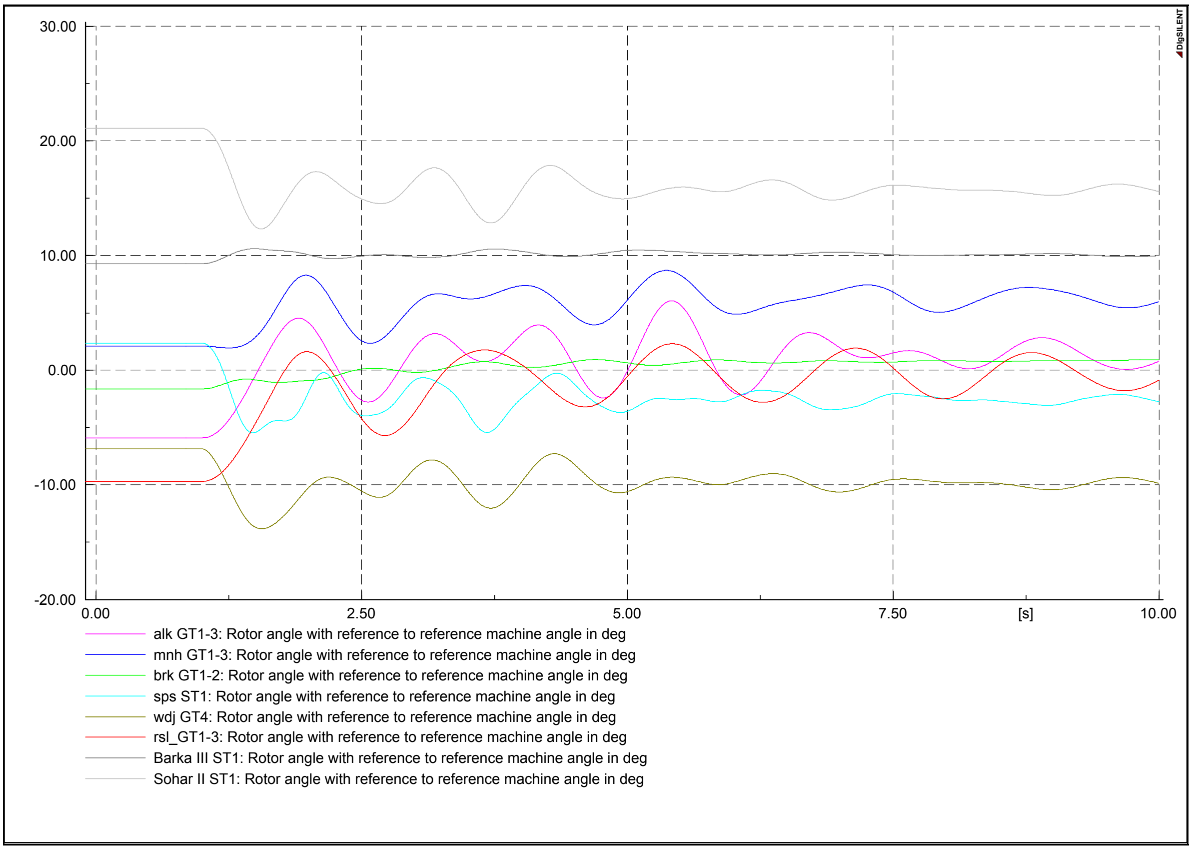

Figure 3. Rotor angle response to interconnection outage (Oman imports 400MW from UAE).