Chapter 5

Tests on power system

5.1 The description of test system

In this chapter, the dynamic equivalent program described in chapter4 has been used for calculating the data, network, generators and control eqiupment, for reduced system. The power system of EGAT (Electricity Generating Authority of Thailand) is used for test system. A map showing the geographical extent and the principle transmission lines of EGAT power system is given in Figure 5.1. EGAT power system has been used for studies of the performance, load flow calculations, short circuit calculations and transient stability studies of the system. These studies are performed in terms of both actual system and reduced system.

The data , network, generators and control equipment have been supplied by EGAT. Only the high voltage bus (=> 115 KV) and generator buses are included in the database of the system. Loads and shunt impedances on low voltage buses are transfered to the corresponding high voltage buses. The database includes 4332 +j 2228 MVA load, 229 buses, 257 lines and 50 generators (in service). Total capacity of generator in the system is 6400 MVA. The database of the system is too big to be printed in this thesis report. But it is available in our computer.

5.2 Tests on power system

The test on EGAT power system are broken down into mainly two sets. The first set is divided into three tests as follows:

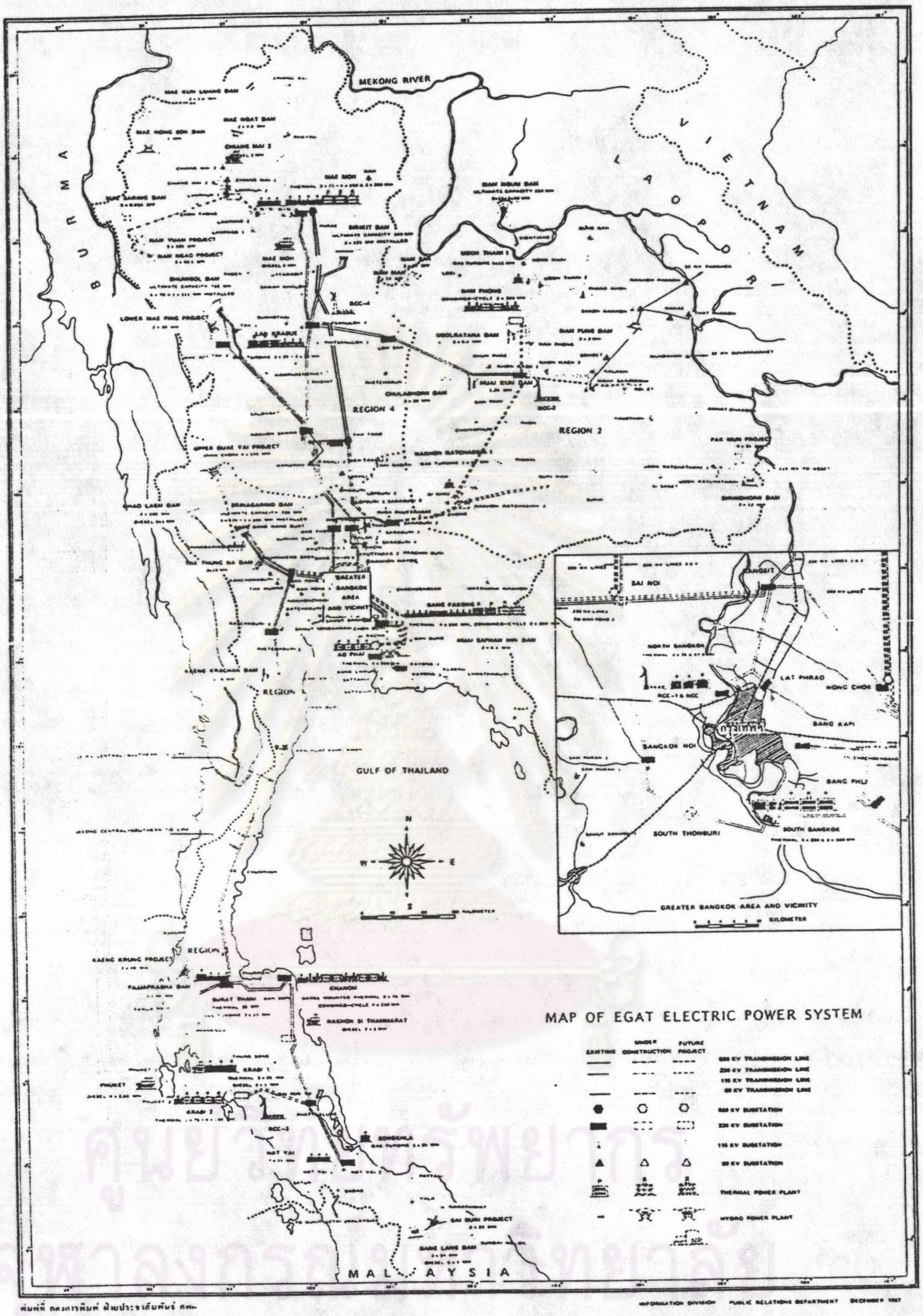

Figure 5.1 A map showing the geographical extent and the principle transmission lines of EGAT power system

- load flow calculation on the actaul system (EGAT).
- short circuit calculation on the actual system (EGAT).
- transient stability studies on the actual system (EGAT).

The second set is divided into three tests as follows:

- load flow calculation on the reduced system of EGAT.
- short circuit calculation on the reduced system of EGAT.
- transient stability studies on the reduced system of EGAT.

The two test sets are performed by using the power system simulator package (SIMPOW) which is executed on the VAX-STATION 2000 computer. The computer is installed at the fourth floor of Electrical Engineering Building, Chulalongkorn University, Bangkok, Thailand.

5.2.1 Load flow calculation on the actual system

The objective of load flow calculation on the actual system is to study steady state performance, bus voltage, power flow in transmission lines, power production and spinning reserve, of power system. The BPK-S1 at BANG PAKONG power station is slack bus of the system. Load flow calculation is divided into two case as follows:

- case no 1: power flow from bus CP-115 to bus PKK-115 around $120 - j\,40$ MVA.
- case no 2: power flow from bus CP-115 to bus PKK-115 around $-114 - j\,17$ MVA.

Load flow case no 1 is used for base-case of case no 2. In case no 2, total generation in southern area is increased around 112 %. The solutions of load flow case no 1 and case no 2 are given in Figure A4.1.1 - A4.2.5 at appendix 4. The power flows in transmission lines (tie lines) of case no 1 and no 2 are given in table 5.1.

Table 5.1 Power flows in transmission lines (tie lines)in the actual system

LINE BETWEEN SUBSTATION		TOTAL CIRCUITS	TOTAL POWER FLOW (MVA)	
			LOAD FLOW CASE 1	load flow case 2
MM3-230	PL2-230	2	366 - j 14	366 - j 14
MM3-230	TTK-230	1	204 + j 9	204 + j 9
LS-230	KK-230	2	296 - j 26	296 - j 26
BPK-230	NCO-230	4	760 + j 204	608 + j 204
BPK-230	BPL-230	2	344 + j 24	262 + j 30
PKK-115	CP-115	2	120 - j 28	-112 - j 12

5.2.2 Short circuit calculation on the actual system

The objective of short circuit calculation on the actual system is to calculate short circuit current during steady state AC-condition. The load flow solution of case no 1 is used for initial condition of short circuit calculation. The short circuit calculation is divided into four cases as follows:

- case no 1: Three phase fault to ground occurred at bus NCO-230
- case no 2: Three phase fault to ground occurred at bus PL2-230
- case no 3: Three phase fault to ground occurred at bus CP-115
- case no 4: Three phase fault to ground occurred at bus BPK-S2

The solutions of short circuit calculation are given in table 5.2.

Table 5.2 Short circuit current and power in the actual system

CASE NO	PHASE VOLTAGE		SHORT CIRCUIT CURRENT	SHORT CIRCUIT POWER (MVA)
	PRE FAULT	POST FAULT		
1	137.6 KV	0 KV	21.84 KA	3005
1	-7.8 DEG	-90 DEG	93.30 DEG	
2	140.1 KV	0 KV	7.84 KA	1098
2	3.9 DEG	0 DEG	104.8 DEG	
3	70.3 KV	0 KV	4.28 KA	300
3	-17.7 DEG	0 DEG	81.30 DEG	
4	12.4 KV	0 KV	171.60 KA	2127
4	-1.0 DEG	-90 DEG	91.9 DEG	

5.2.3 Transient stability studies on the actual system

Transient stability studies on the actual system are carried out with two types of generators model; TYPE 1 and TYPE 2. All generators have TYPE BBC1 excitaion system. TYPE HT1 and TYPE ST1 turbine model are used for modelling of hydro and steam turbine respectively. TYPE ST2 and TYPE SG2 governor model are used for governing system of hydro and steam turbine respectively. The objectives of transient stability studies can be divided as follows:

- Investigation of the behaviour of generator in the actual system after fault, short circuit, generator tripping and line outage.
- Studies of dynamic performance of the actual system.
- Identification of coherent generators.

The studies is divided into five cases as follows:

- case no 1: The three phase fault occurred at bus NCO-230. The fault is cleared after 120 ms.
- case no 2: The three phase fault occurred on line no 2 which link between bus PL2-230 and bus MM3-230 near bus PL2-230. The fault is cleared by permanent disconnected the line after 150 ms.
- case no 3: The three phase fault occurred on line no 2 which link between bus CP-115 and bus PKK-115 near bus PKK-115. The fault is cleared by permanent disconnected the line after 150 ms.
- case no 4: The three phase fault occurred at bus BPK-S2. The fault is cleared after 50 ms by tripping the generator BPK-S2 which has 680 MVA capacity. Before the fault occurred the generator supplyes 480 + j 170 MVA apparent power to the system.
- case no 5: The three phase fault occurred on line no 2 which link between bus CP-115 and bus PKK-115 near bus CP-115. The fault is cleared by permanent disconnected the line after 170 ms.

The load flow solution case no 1 is used for initial condition of transient stability studies case no 1 - 4. The load flow solution case no 2 is used for initial condition of transient stability case no 5. The results of transient stability studies, rotors angle, bus voltage, power flow in some lines and frequency, are given in appendix 3.

5.2.4 Tests on reduced system

From the results of transient stability studies on the actual system, the original 50 generators were combined into 6 coherent groups. The generators within each of the 6 coherent groups are described below:

- Group no 1 consisted of 6 generators: BPK-S1, BPK-S2, BPK-C1, BPK-G1, BPK-G2 and BPK-G3, in the EAST AREA.
- Group no 2 consisted of 10 generators: CLB-H1, CLB-H2, UR-H1, UR-H2, UR-H3, SRD-H1, SRD-H2, SRD-H3, NM-H1 and NM-H2, in the NORTH EAST AREA.
- Group no 3 consisted of 7 generators: KHL-H1, KHL-H2, SNR-H1, SNR-H2, SNR-H3, TN-H1 and TN-H2, in the WEST AREA.
- Group no 4 consisted of 12 generators: BB-H12, BB-H34, BB-H56, SK-H1, SK-H2, MM2-S1, MM2-S2, MM2-S3, MM3-S4, MM3-S5, MM3-S7 AND MM3-S7 in the NORTH AREA.
- Group no 5 consisted of 5 generators: SB-S1, SB-S2, SB-S3, SB-S4 and SB-S5 in the BANGKOK AREA.
- Group no 6 consisted of 10 generators: BLG-H1, BLG-H2, BLG-H3, RPB-H1, RPB-H2, RPB-H3, KN-S1, KN-S2, KA-S1 and KA-S2 in SOUTH AREA.

A map showing the approximate geographical location of the coherent generator groups is shown in Figure 4.1. The buses which are involved in switching operation, buses for which responses were of interest and buses for each the tie lines connecting the substudies-system were retained in the reduced system. The program were sequentailly applied to compute an equivalent with 51 buses, 57 lines and 6 equivalent generators. A map showing the capacity of equivalent generators and simplified network of reduced system is shown in Figure 5.2. After the equivalent data has already been calculated , the tests on reduced system are performed.

5.2.5 Load flow calculation on the reduced system

In the reduced system, the power flow, bus voltage in the retained part of the network should be preserved. Similary, power production should be preserved. Load flow calculation on the reduced system are performed for finding the initial condition for transient stability studies on reduced system. The BUSEQ1 is slack bus in

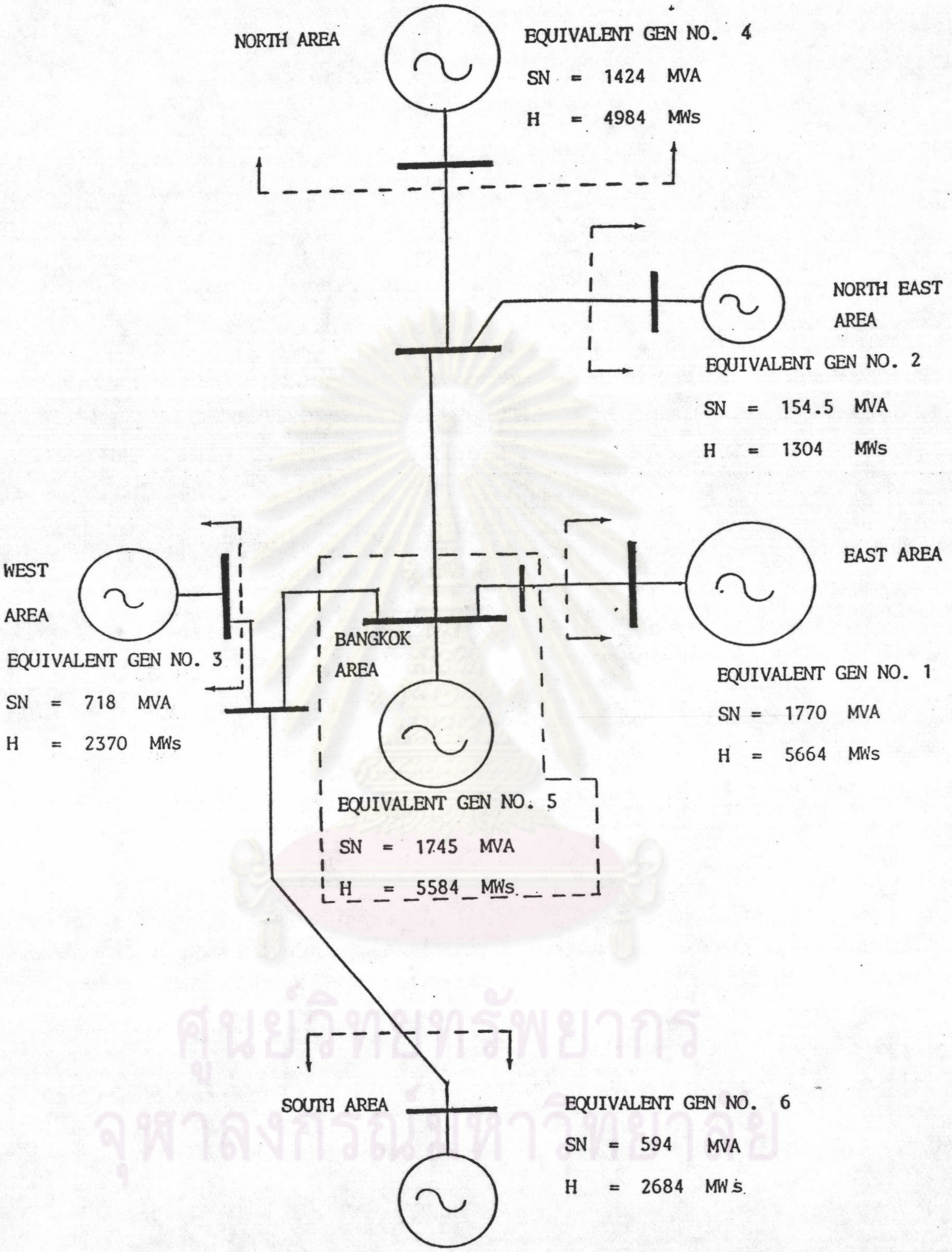

Figure 5.2 A map showing the capacity of equivalent generators and simplified network of reduced system

reduced system. The load flow solutions of reduced system are given in Figure A4.1.6 and Figure A4.2.6 of appendix 4. The power flows in transmission lines (tie lines) of case no 1 and no 2 are given in table 5.3.

Table 5.3 Power flows in transmission lines (tie lines) in the reduced system

LINE BETWEEN SUBSTATION		TOTAL CIRCUITS	TOTAL POWER FLOW (MVA)	
			LOAD FLOW CASE 1	LOAD FLOW CASE 2
MM3-230	PL2-230	2	366 - j 16	366 - j 16
MM3-230	TTK-230	1	204 + j 9	204 + j 9
LS-230	KK-230	2	294 - j 28	296 - j 26
BPK-230	NCO-230	4	760 + j 204	608 + j 208
BPK-230	BPL-230	2	342 + j 24	262 + j 30
PKK-115	CP-115	2	120 - j 28	-112 - j 12

5.2.6 Short circuit calculation on the reduced system

The short circuit calculations on the reduced system are performed for calculating short circuit current. There are four cases of short circuit calculation similar to the case on the actual system. The solutions of short circuit calculation are given in table 5.4.

Table 5.4 Short circuit current and power in reduced system

CASE NO	PHASE VOLTAGE		SHORT CIRCUIT CURRENT		SHORT CIRCUIT POWER (MVA)
	PRE FAULT	POST FAULT			
1	137.6 KV	0 KV	21.39	KA	2943
1	-7.8 DEG	-90 DEG	95.60	DEG	
2	140.1 KV	0 KV	7.94	KA	1112
2	3.9 DEG	0 DEG	104.9	DEG	
3	70.0 KV	0 KV	4.30	KA	301
3	-17.9 DEG	0 DEG	82.30	DEG	
4	12.4 KV	0 KV	170.08	KA	2109
4	-1.0 DEG	-90 DEG	92.1	DEG	

5.2.7 Transient stability studies on the reduced system

The objective of the study is to investigate the behaviour of equivalent generators and dynamic performance of reduced system. The results of transient stability studies on reduced system are given in appendix 3. In the figures of appendix 3 are given results from computer calculations applying the fault-types and fault locations as mentioned above (chapter 4) to the full-scale and the reduced system. Voltage of the main buses, rotor angle of important generators, system frequency and power flows in transmission lines are compared.

5.3 Discussions

As mentioned earlier, the steady state and dynamic performance of the reduced system should be preserved. In this section the performances of the actual and reduced system are compared and discussed. The comparisons are divided into three topics as follows:

- The comparison of load flow calculations
- The comparison of short circuit calculations
- The comparison of transient stability studies

5.3.1 The comparison of load flow calculations

The load flow solutions for the actual and reduced system are illustrated by the simplified network which is shown in Figure A4.1.1 - A4.2.7 in appendix 4 and demonstrate that the accuracy is very satisfactory. The comparison of the power flows in some tie lines between the actual and reduced system is given in table 5.5

Table 5.5 The difference of power flows in tie lines between the actual and reduced system

LINE BETWEEN SUBSTATION		THE DIFFERENCE OF POWER FLOWS (MVA)	
		LOAD FLOW CASE NO. 1	LOAD FLOWS CASE NO.2
MM3-230	PL2-230	0 + j 2	0 + j 2
MM3-230	TTK-230	0 + j 0	0 + j 0
LS-230	KK-230	2 + j 2	0 + j 0
BPK-230	NCO-230	0 + j 0	0 - j 4
BPK-230	BPL-230	2 + j 0	0 + j 0
PKK-115	CP-115	0 + j 0	0 + j 0

The maximum difference for power flows is about 1 MW(MVAR)/circuit. These results show that when the network is reduced by using the method descirbed in chapter 2 the power folws in the reduced system can be preserved.

5.3.2 The comparison of short circuits calculations

From the summaries of short circuits calculations which are shown in table 5.2 and 5.4, we can obtain the difference of short circuits current between the actual and reduced system, as shown in table 5.6

Table 5.6 The differences of short circuits current and power between the actual and reduced system

SHORT CIRCUIT CASE NO.	THE DIFFERENCE OF SHORT CIRCUIT	
	CURRENT %	POWER %
1	2.06*	2.06*
2	1.28	1.28
3	0.40	0.33
4	0.89	0.88

Note: The differences are absolute value.

Table 5.6 shows that the short circuits current and power in reduced system are quite the same as short circuits current and power in the actual system. The maximum difference is about 2.06 % which is shown in case no.1. These differences are quite small and they show that when the network is reduced by using the method in chapter 2 and the generating units models are aggregated by using the method in chapter 3, the short circuits current in the reduce system can be preserved.

5.3.3 The comparison of transient stability studies

The comparison of the network sizing, computation time and dynamic performance, between the actual and the reduced system are discussed in this section. The result of the transient stability studies, rotor angle, power flows, bus voltage and frequency, for the actual and reduced are compared in appendix 3. As shown, the accuracy of the reduced system is satisfactory. The CPU time for all cases of transient stability simulation using the reduced were about 20 - 30 % of CPU time using the actual system. The comparison of the network sizing and CPU time for the simulations between the actual and the reduced system are given in table 5.7 and 5.8 respectively. The conclusion of stability is given in table 5.9

Table 5.7 Size comparison between the actual and reduced system.

TRANSIENT STABILITY STUDIES CASE NO.1 ,2, 3, 4 AND 5			
COMPONENT IN THE NETWORK	ACTUAL SYSTEM	REDUCED SYSTEM	REDUCTION RATIO (REDUCED/ACTUAL)x100 %
No. of machines	50	6 (7)	12% (14%)
No. of buses	229	51 (52)	22.22% (22.23%)
No. of lines	257	57	22.11%

Note: The value in parenthesis for transient stability case no 4.

Table 5.8 CPU. time comparison between actual and reduced system.

TRANSIENT STABILITY STUDIES CASE NO.1 ,2, 3, 4 AND 5				
CASE NO.	SIMULATION TIME (Secs)	CPU TIME (Secs)		REDUCTION RATIO (REDUCED/ACTUAL)x100 %
		ACTUAL SYSTEM	REDUCED SYSTEM	
1	15	3237	601	18.58
2	15	4713	870	18.45
3	10	2008	590	29.38
4	15	3059	707	23.11
5	5	3323	454	13.66

Note: CPU. times are measured on VAX-STATION 2000 computer.

Table 5.9 Conclusion of stability studies

STABILITY CASE NO.	LOAD FLOW CASE NO.	COMMENT	
		ACTUAL SYSTEM	REDUCED SYSTEM
1	1	Stable and Damp	Stable and Damp
2	1	Stable and Damp	Stable and Damp
3	1	Stable and Damp	Stable and Damp
4	1	Stable and Damp	Stable and Damp
5	2	Unstable	Unstable