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Impacts of Long Time Outage of Transformer T2 on Power Supply Reliability at Substation FVW

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1. Introduction

This report is to estimate impacts of long time outage of the transformer T2 on power supply reliability at Substation FVW.

The simplified single-line diagram of substation FVW is shown in Figure 1 and the full single-line diagram is given as an attachment.

When T2 is in service, Breaker 2CB56 is normally open. When a failure happens at either side, the breaker 12CB1 or 25CB2 will be opened (depending on which side a fault occurs at) and 2CB56 will be automatically and instantly closed so that the feeders will not lose power supply. If T2 is out-of-service, both 12kv and 25kv feeders will be supplied only from 1L48, resulting in a radial configuration without any backup power source.

The purpose of this study is to quantify and compare power supply reliability levels at the two feeder groups (12kv feeders and 25 kV feeders) for the two cases: (1) The transformer T2 is in service and (2) T2 is out-of-service.

2. Data

The failure data of all the components is provided by the APD department and shown in Table 1.

Table 1 Failure data of components

Component	Failure frequency	Repair time (hours)
1L33	1 failure in 10 years	4
1L48	1 failure in 10 years	4
T1	1 failure in 60 years	24
T2	1 failure in 60 years	24
T10	1 failure in 30 years	48
12CB1	1 failure in 20 years	48
25CB2	1 failure in 20 years	48
25CB56	1 failure in 20 years	48

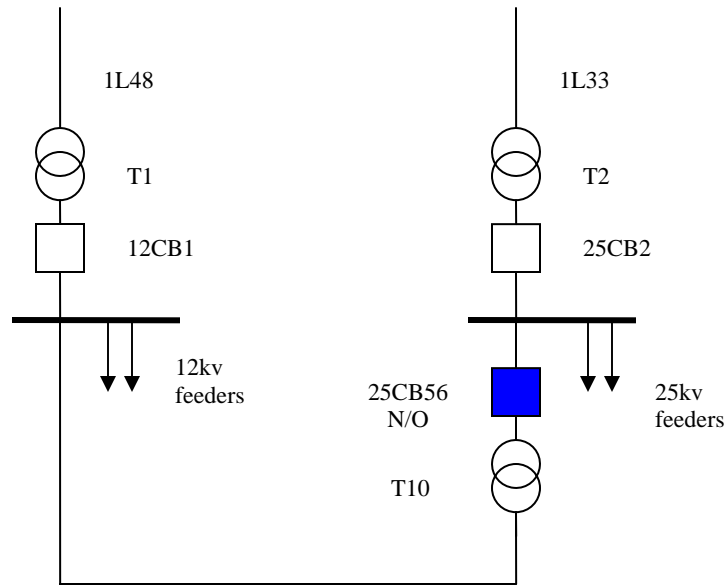


Figure 1 Simplified single-line diagram of FVW substation

3. Reliability network model and computing tool

The problem in the study can be modeled using the reliability networks as shown in Figures 2 - 5. The computing program called NETREL was used to perform the evaluation. This program can assess reliability of a network composed of parallel and series structures and their combinations.

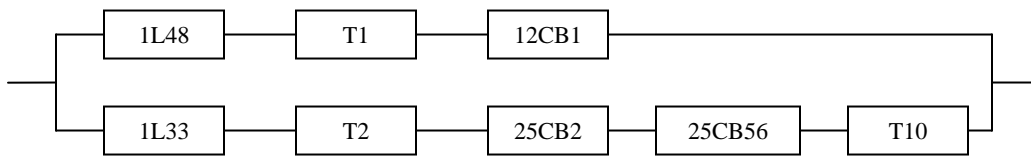


Figure 2 Network model for reliability evaluation of 12kv feeders with T2 in service

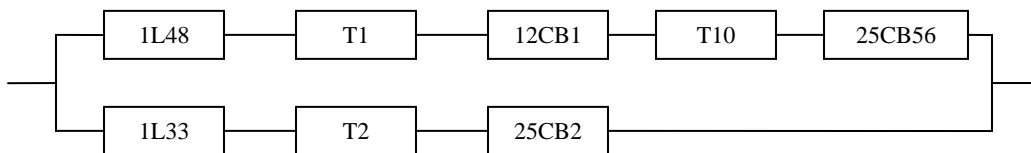


Figure 3 Network model for reliability evaluation of 25kv feeders with T2 in service

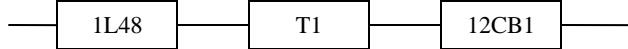


Figure 4 Network model for reliability evaluation of 12kv feeders with T2 out-of-service

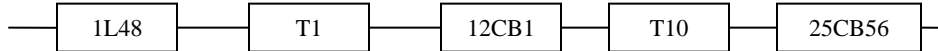


Figure 5 Network model for reliability evaluation of 25kv feeders with T2 out-of-service

4. Results

The average outage frequency, outage time and unavailability at the 12kv and 25kv feeders for the cases of T2 in service and out-of-service are given in Table 2.

The following observations can be made:

- The reliability level at both 12kv and 25kv feeders in the case of T2 out-of-service is much lower than that in the case of T2 in service. The indices provided a quantitative comparison.
- The average outage frequency at either 12kv or 25kv feeders in the case of T2 out-of-service is larger than the failure frequency of any component while the average outage time at the feeders is between the repair times of the components.
- The values of unavailability at both 12kv and 25kv feeders even in the case of T2 out-of-service are still very small. This is due to the fact that the failure data (failure frequencies) of all the components are small.

Table 2 Outage indices at the 12kv and 25kv feeders

Feeders	T2 status	Outage frequency (outage/year)	Outage time (hours/outage)	Unavailability
12kv	In service	0.000228	11.52	0.0000003
12kv	Out-of-service	0.166628	19.20	0.0003653
25kv	In service	0.000228	11.52	0.0000003
25kv	Out-of-service	0.249833	28.81	0.0008217

5. Outputs from running the NETREL program

(1) The results for 12kv feeders with T2 in service

Input data

System capacity: Not specified

Component data

fr	to	par	failure frequency (f/yr)	repair time (hrs)	age fail prob.
1	2		0.10000 f	4.0000	0.0000000
1	3		0.10000 f	4.0000	0.0000000
2	4		0.01667 f	24.0000	0.0000000
3	5		0.01667 f	24.0000	0.0000000
4	8		0.05000 f	48.0000	0.0000000
5	6		0.05000 f	48.0000	0.0000000
6	7		0.05000 f	48.0000	0.0000000
7	8		0.03333 f	48.0000	0.0000000

Output results

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	2	0.1000	4.00
2:	1	3	0.1000	4.00
3:	2	4	0.0167	24.00
4:	3	5	0.0167	24.00
5:	4	8	0.0500	48.00
6:	5	6	0.0500	48.00
7:	6	7	0.0500	48.00
8:	7	8	0.0333	48.00

Series 1: 1 2
with 3: 2 4

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	4	0.1167	6.86
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	4	8	0.0500	48.00
5:	5	6	0.0500	48.00
6:	6	7	0.0500	48.00
7:	7	8	0.0333	48.00

Series 1: 1 4
with 4: 4 8

FAILURE REPAIR

N0	FROM	TO	RATE (f/yr)	TIME (hr/f)
1:	1	8	0.1667	19.20
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	5	6	0.0500	48.00
5:	6	7	0.0500	48.00
6:	7	8	0.0333	48.00

Series 2: 1 3
with 3: 3 5

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.1667	19.20
2:	1	5	0.1167	6.86
3:	5	6	0.0500	48.00
4:	6	7	0.0500	48.00
5:	7	8	0.0333	48.00

Series 2: 1 5
with 3: 5 6

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.1667	19.20
2:	1	6	0.1667	19.20
3:	6	7	0.0500	48.00
4:	7	8	0.0333	48.00

Series 2: 1 6
with 3: 6 7

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.1667	19.20
2:	1	7	0.2167	25.85
3:	7	8	0.0333	48.00

Series 2: 1 7
with 3: 7 8

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.1667	19.20
2:	1	8	0.2500	28.81

Parallel 2: 1 8
with 1: 1 8

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
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1: 1 8 0.0002 11.52

The system failure frequency is 0.000228 f/yr
with a repair time of 11.522911 hr/f

The system availability index is 0.9999996999 or 8759.997371 hr/yr
unavailability index is 0.0000003001 or 0.002629 hr/yr

(2) The results for 12kv feeders with T2 out-of-service

Input data

System capacity: Not specified

Component data

fr	to	par	failure frequency (f/yr)	repair time (hrs)	age fail prob.
1	2		0.10000 f	4.0000	0.0000000
2	3		0.01667 f	24.0000	0.0000000
3	4		0.05000 f	48.0000	0.0000000

Output results

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	2	0.1000	4.00
2:	2	3	0.0167	24.00
3:	3	4	0.0500	48.00

Series 1: 1 2
with 2: 2 3

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	3	0.1167	6.86
2:	3	4	0.0500	48.00

Series 1: 1 3
with 2: 3 4

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	4	0.1667	19.20

The system failure frequency is 0.166628 f/yr
with a repair time of 19.203494 hr/f

The system availability index is 0.9996347212 or 8756.800157 hr/yr
unavailability index is 0.0003652788 or 3.199843 hr/yr

(3) The results for 25kv feeders with T2 in service

Input data

System capacity: Not specified

Component data

fr	to	par	failure frequency (f/yr)	repair time (hrs)	age fail prob.
1	2		0.10000 f	4.0000	0.0000000
1	3		0.10000 f	4.0000	0.0000000
2	4		0.01667 f	24.0000	0.0000000
3	5		0.01667 f	24.0000	0.0000000
4	6		0.05000 f	48.0000	0.0000000
5	8		0.05000 f	48.0000	0.0000000
6	7		0.03333 f	48.0000	0.0000000
7	8		0.05000 f	48.0000	0.0000000

Output results

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	2	0.1000	4.00
2:	1	3	0.1000	4.00
3:	2	4	0.0167	24.00
4:	3	5	0.0167	24.00
5:	4	6	0.0500	48.00
6:	5	8	0.0500	48.00
7:	6	7	0.0333	48.00
8:	7	8	0.0500	48.00

Series 1: 1 2
with 3: 2 4

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	4	0.1167	6.86
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	4	6	0.0500	48.00
5:	5	8	0.0500	48.00

6:	6	7	0.0333	48.00
7:	7	8	0.0500	48.00

Series	1:	1	4
with	4:	4	6

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	6	0.1667	19.20
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	5	8	0.0500	48.00
5:	6	7	0.0333	48.00
6:	7	8	0.0500	48.00

Series	1:	1	6
with	5:	6	7

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	7	0.2000	24.01
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	5	8	0.0500	48.00
5:	7	8	0.0500	48.00

Series	1:	1	7
with	5:	7	8

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.2500	28.81
2:	1	3	0.1000	4.00
3:	3	5	0.0167	24.00
4:	5	8	0.0500	48.00

Series	2:	1	3
with	3:	3	5

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.2500	28.81
2:	1	5	0.1167	6.86
3:	5	8	0.0500	48.00

Series	2:	1	5
with	3:	5	8

N0	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	8	0.2500	28.81
2:	1	8	0.1667	19.20

```

-----
Parallel  2:   1   8
with     1:   1   8
-----

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```

-----
                FAILURE  REPAIR
                RATE    TIME
NO  FROM  TO    (f/yr)  (hr/f)
1:   1    8      0.0002  11.52
-----

```

The system failure frequency is 0.000228 f/yr
with a repair time of 11.522911 hr/f

The system availability index is 0.9999996999 or 8759.997371 hr/yr
unavailability index is 0.0000003001 or 0.002629 hr/yr

(4) The results for 25kv feeders with T2 out-of-service

Input data

System capacity: Not specified

Component data

```

-----
fr   to  par  failure  repair  age fail
      1:  2:  failure  time    prob.
      1:  2:  frequency
      1:  2:  (f/yr)   (hrs)
-----
1    2    0.10000 f    4.0000  0.0000000
2    3    0.01667 f   24.0000  0.0000000
3    4    0.05000 f   48.0000  0.0000000
4    5    0.03333 f   48.0000  0.0000000
5    6    0.05000 f   48.0000  0.0000000
-----

```

Output results

```

-----
                FAILURE  REPAIR
                RATE    TIME
NO  FROM  TO    (f/yr)  (hr/f)
1:   1    2      0.1000  4.00
2:   2    3      0.0167  24.00
3:   3    4      0.0500  48.00
4:   4    5      0.0333  48.00
5:   5    6      0.0500  48.00
-----

```

```

Series  1:   1   2
with    2:   2   3
-----

```

```

-----
                FAILURE  REPAIR
                RATE    TIME
NO  FROM  TO    (f/yr)  (hr/f)
1:   1    3      0.1167  6.86
-----

```

2:	3	4	0.0500	48.00
3:	4	5	0.0333	48.00
4:	5	6	0.0500	48.00

Series	1:	1	3
with	2:	3	4

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	4	0.1667	19.20
2:	4	5	0.0333	48.00
3:	5	6	0.0500	48.00

Series	1:	1	4
with	2:	4	5

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	5	0.2000	24.01
2:	5	6	0.0500	48.00

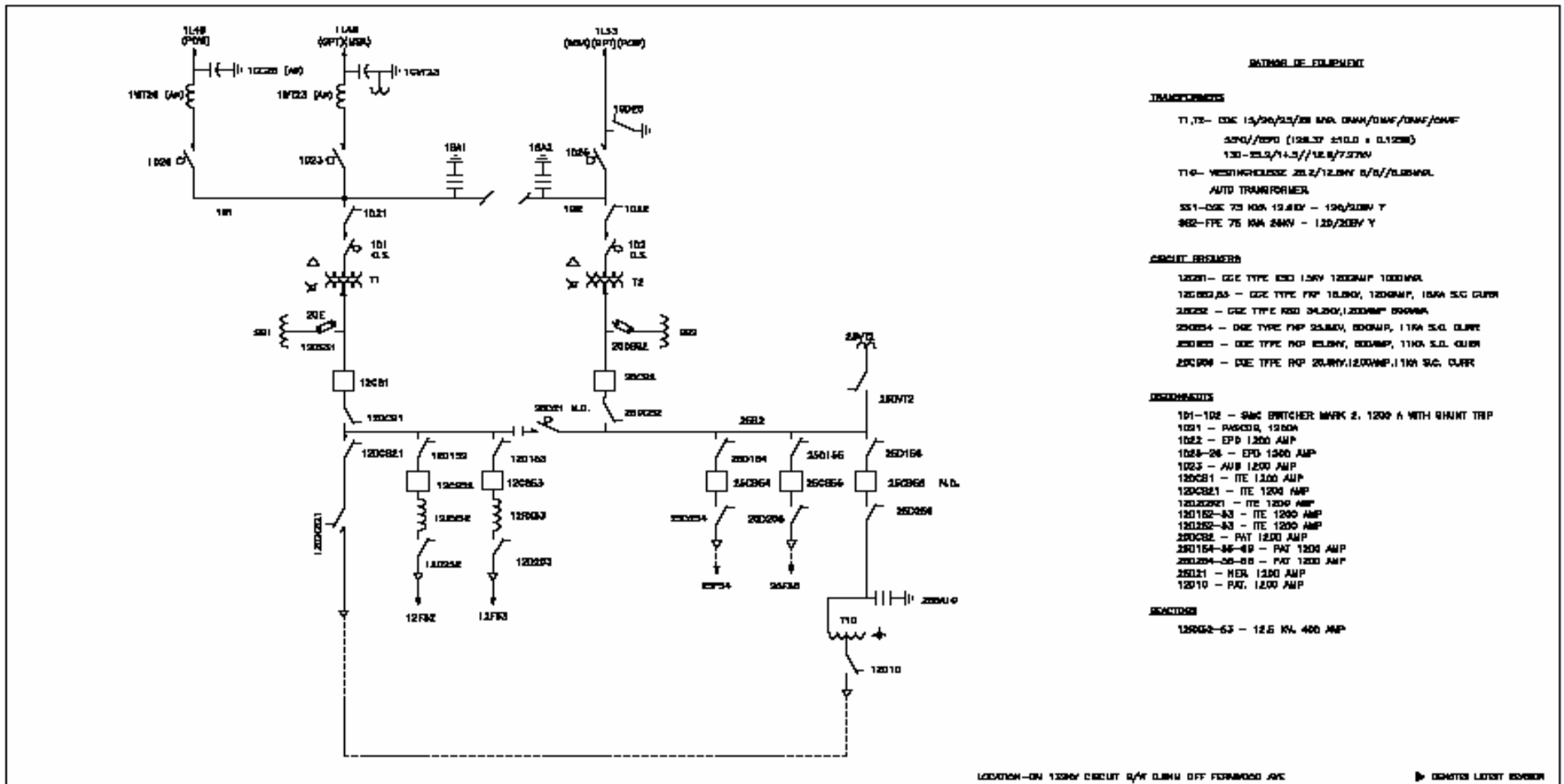
Series	1:	1	5
with	2:	5	6

NO	FROM	TO	FAILURE RATE (f/yr)	REPAIR TIME (hr/f)
1:	1	6	0.2500	28.81

The system failure frequency is 0.249833 f/yr
with a repair time of 28.810336 hr/f

The system availability index is 0.9991783352 or 8752.802217 hr/yr
unavailability index is 0.0008216648 or 7.197783 hr/yr

6. Attachment - the full single-line diagram of substation FVW



R	DATE	REVISION	APP DR	R	DATE	REVISION	APP DR	R	DATE	REVISION	APP DR	STATION OPERATING ONELINE DIAGRAM - MC
					18	04-03-17	UPDATE EQUIP. RATING FOR 250CB1	DAL	KH			 FORESTVIEW (FVW)
					18	03-12-29	ADD C.S. 10 & LABEL SYMBOL TO 101 & 102	DAL	KH			
					17	03-08-04	ADD INT28 & 10226	DAL	KH			
					16	08-03-11	ADD DISCONNECTS TO RATINGS LIST	PC	DL			
					15	04-06-14	UPDATE EQUIP. RATING LIST FOR 120CB2					