

# 1 Transpower forced outage data

## 1.1 Data for Centralised Data System – Enduring Forced Asset Outages

### HVAC

The data is provided as an Excel file and is a list of forced outages of Transpower transmission circuits, transformers, capacitor banks, synchronous Condensers, and the Islington SVC.

The fields are:

Ident: Incident Identifier that links all the records associated with one fault. Flt\_Item: The item / equipment causing the forced outage. There is usually one of these per incident. The exception is for a double circuit fault. Rem\_Item: Any equipment in the above categories that has been forced out of service. Date Time: Date Time: Date, Time Duration: Outage Duration in minutes. Notes:

Forced Outages are those for which the equipment was tripped or manually taken out of service within 24 hours of the fault occurring or being discovered. A circuit is deemed out of service if any circuit breaker is open. In some cases, a forced outage may be recorded against a circuit section rather than the whole circuit, in particular for three terminal circuits. A transformer is deemed out of service if either the HV or LV circuit breaker is open (an open CB on the tertiary winding is generally not considered to constitute a transformer outage). A trip – autoreclose-trip sequence is shown as one incident (with one identifier) if the autoreclose was unsuccessful because of a persisting fault. If a second fault occurs or is discovered when attempting to return equipment to service, a second incident is recorded with a second identifier, e.g. failed autoreclose because of a protection fault; or a transformer cannot be returned to service because of a CB problem. A number of outages within a relatively short space of time will generally be recorded under one identifier if they all had the same cause, e.g. a tree causes three trippings within 10 minutes. If the outages are caused by separate faults they will have separate identifiers, e.g. if a circuit trips for lightning 3 times in 10 minutes. Unplanned outages caused by a delayed return-to-service after planned maintenance works are not included. Whilst Transpower has used reasonable endeavours to ensure that this data is accurate, there is no guarantee that it is error free. HVDC

The data is provided as an Excel file and is a list of forced outages on Transpower's HVDC system.

The fields are: Occurrence: Date and Time of tripping. RTS\_Date: Date and Time of return to service. Terminal: Equipment affected Notes:

HVDC Forced outages include both automatic and manual trippings. An HVDC outage is categorised as forced if it occurs within 7 days of a fault being discovered. System disturbances and restrictions are not included.

Whilst Transpower has used reasonable endeavours to ensure that this data is accurate, there is no guarantee that it is error free.

```
import os
path='/home/humed/python/notebooks'
#os.listdir(path)

from pandas import *
import pandas
%config InlineBackend.figure_format = 'svg'
```

```
hvac = ExcelFile('HVAC_forced_outages_data_1999_Jun2012.xls')
```

```
hvac = hvac.parse(sheetname='HVAC',na_values=['.'])
```

```
hvac.tail(100)
```

	Ident	Flt_Item	Date	Time	Rem_Item	Duration
9546	SN12206		2012-05-29	00:00:00	1608	KIN-LFD2 90
9547	SN12206		2012-05-29	00:00:00	1608	OKE-OWH1 87
9548	SN12208	OTA-WKM1	2012-05-30	00:00:00	1230	OTA-WKM1 0
9549	SN12209	ARI-KIN1	2012-05-31	00:00:00	1357	ARI-KIN1 158
9550	SN12210	RDF-TF-1	2012-05-31	00:00:00	2019	RDF-TF-1 93
9551	SS12074	ADD HEI	2012-06-01	00:00:00	154	ADD-TF-7 46
9552	SS12076	ADD-TF-3	2012-06-01	00:00:00	839	ADD-TF-3 1717
9553	SN12212	KIN-LFD-TRK1	2012-06-01	00:00:00	1347	KIN-LFD-TRK1 0
9554	SN12213	ROT-DS-366	2012-06-01	00:00:00	2014	ROT-TF-5 42
9555	SN12213		2012-06-01	00:00:00	2038	ROT-TRK1 4
9556	SN12214	EDG-KAW2	2012-06-02	00:00:00	1416	EDG-KAW2 199
9557	SN12215	OTA-WKM2	2012-06-02	00:00:00	1941	OTA-WKM2 0
9558	SN12216	FHL-TUI1	2012-06-04	00:00:00	1705	FHL-TUI1 0
9559	SN12217	GIS-TUI1	2012-06-05	00:00:00	1357	GIS-TUI1 0
9560	SN12218	TKH-WAI1	2012-06-05	00:00:00	1549	TKH-WAI1 0
9561	SN12218		2012-06-05	00:00:00	1549	WAI-TF-5 0
9562	SN12219	TKH-WAI1	2012-06-05	00:00:00	1953	TKH-WAI1 0
9563	SN12219		2012-06-05	00:00:00	1953	WAI-TF-5 0
9564	SN12220	TKH-WAI1	2012-06-05	00:00:00	2229	TKH-WAI1 708
9565	SN12220		2012-06-05	00:00:00	2229	WAI-TF-5 708
9566	SN12222	GFD-HAY1	2012-06-06	00:00:00	354	GFD-HAY1 566
9567	SN12222		2012-06-06	00:00:00	354	GFD-TF-6 567
9568	SS12078	COL-OTI2	2012-06-06	00:00:00	752	COL-OTI2 0
9569	SS12079	ISL-KIK1	2012-06-06	00:00:00	826	ISL-KIK1 0
9570	SS12080	ISL-KIK1	2012-06-06	00:00:00	832	ISL-KIK1 0
9571	SS12080		2012-06-06	00:00:00	832	ISL-KIK1 63
9572	SS12081	ISL-WPR-CUL-KIK2	2012-06-06	00:00:00	909	ISL-WPR-CUL-KIK2 20
9573	SS12081		2012-06-06	00:00:00	909	CUL-TF-22 21
9574	SS12081		2012-06-06	00:00:00	909	WPR-TF-12 21
9575	SS12082	ISL-WPR-CUL-KIK3	2012-06-06	00:00:00	948	ISL-WPR-CUL-KIK3 8
9576	SS12082		2012-06-06	00:00:00	948	CUL-TF-23 9
9577	SS12082		2012-06-06	00:00:00	948	WPR-TF-13 10
9578	SS12083	ISL-WPR-CUL-KIK3	2012-06-06	00:00:00	1125	ISL-WPR-CUL-KIK3 6
9579	SS12083		2012-06-06	00:00:00	1125	CUL-TF-23 7
9580	SS12083		2012-06-06	00:00:00	1125	WPR-TF-13 8
9581	SS12084	ISL-WPR-CUL-KIK3	2012-06-06	00:00:00	1136	ISL-WPR-CUL-KIK3 8
9582	SS12084		2012-06-06	00:00:00	1136	CUL-TF-23 9
9583	SS12084		2012-06-06	00:00:00	1136	WPR-TF-13 9
9584	SS12085	COL-OTI2	2012-06-06	00:00:00	1136	COL-OTI2 7
9585	SS12085	COL-CLH-APS-OTI1	2012-06-06	00:00:00	1136	COL-CLH-APS-OTI1 0
9586	SS12086	COL-HOR2	2012-06-06	00:00:00	1152	COL-HOR2 10
9587	SS12087	COL-CLH-APS-OTI1	2012-06-06	00:00:00	1216	COL-CLH-APS-OTI1 0
9588	SS12088	COL-CLH-APS-OTI1	2012-06-06	00:00:00	1229	COL-CLH-APS-OTI1 6

9589	SS12089	COL-OTI2	2012-06-06 00:00:00	1304	COL-OTI2	0
9590	SS12089	COL-CLH-APS-OTI1	2012-06-06 00:00:00	1304	COL-CLH-APS-OTI1	0
9591	SS12090	COL-CLH-APS-OTI1	2012-06-06 00:00:00	1311	COL-CLH-APS-OTI1	3
9592	SS12091	COL-CLH-APS-OTI1	2012-06-06 00:00:00	1316	COL-CLH-APS-OTI1	0
9593	SS12092	COL-CLH-APS-OTI1	2012-06-06 00:00:00	1317	COL-CLH-APS-OTI1	143
9594	SS12093	HOR-ISL1	2012-06-06 00:00:00	1403	HOR-ISL1	6
9595	SN12223	WRK-PPI-WKM1	2012-06-06 00:00:00	1426	WRK-PPI-WKM1	0
9596	SS12094	HOR-ISL2	2012-06-06 00:00:00	1433	HOR-ISL2	7
9597	SS12095	ISL Sys_Conditions	2012-06-06 00:00:00	1433	ISL-SVC-3	48
9598	SS12096	ISL-WPR-CUL-KIK3	2012-06-06 00:00:00	1440	ISL-WPR-CUL-KIK3	5
9599	SS12096		2012-06-06 00:00:00	1440	CUL-TF-23	6
9600	SS12096		2012-06-06 00:00:00	1440	WPR-TF-13	7
9601	SS12097	COL-HOR3	2012-06-06 00:00:00	1508	COL-HOR3	7
9602	SS12098	KIK Cust_Fault	2012-06-06 00:00:00	1548	KIK-TF-1	22
9603	SS12098		2012-06-06 00:00:00	1612	KIK-TF-1	12
9604	SS12099	COL-CLH-APS-OTI1	2012-06-06 00:00:00	1601	COL-CLH-APS-OTI1	73
9605	SS12099		2012-06-06 00:00:00	1714	CLH-APS-OTI1	248
9606	SS12100	CLH-TF-1	2012-06-06 00:00:00	2126	CLH-TF-1	1178
9607	SS12800	APS-CLH1	2012-06-06 00:00:00	2142	APS-CLH-COL1	1153
9608	SS12800	APS-CLH1	2012-06-07 00:00:00	1701	APS-CLH1	2569
9609	SS12101	ISL-WPR-CUL-KIK2	2012-06-07 00:00:00	643	ISL-WPR-CUL-KIK2	507
9610	SS12101		2012-06-07 00:00:00	643	CUL-TF-22	508
9611	SS12101		2012-06-07 00:00:00	643	WPR-TF-12	508
9612	SS12102	ISL Sys_Conditions	2012-06-07 00:00:00	644	ISL-SVC-9	153
9613	SN12224	GIS-TUI2	2012-06-07 00:00:00	1415	GIS-TUI2	0
9614	SS12103	ISL-WPR-CUL-KIK2	2012-06-08 00:00:00	0	ISL-WPR-CUL-KIK2	902
9615	SS12103		2012-06-08 00:00:00	0	CUL-TF-22	903
9616	SS12103		2012-06-08 00:00:00	0	WPR-TF-12	906
9617	SN12225	WRK-DS-105	2012-06-12 00:00:00	1101	OKI-WRK1	355
9618	SN12227	ALB-CB-702	2012-06-13 00:00:00	1031	ALB-TF-6	43
9619	SN12806	ALB-TF-6	2012-06-13 00:00:00	1114	ALB-TF-6	37
9620	SN12806		2012-06-13 00:00:00	1708	ALB-TF-6	183
9621	SS12105	ASB-VT-1	2012-06-14 00:00:00	1600	ASB-TF-1	17127
9622	SS12105		2012-06-14 00:00:00	1600	ASB-TF-3	37
9623	SN12228	KAW-VT-26	2012-06-15 00:00:00	800	KAW-TF-6	4874
9624	SS12106	ADD Prot	2012-06-16 00:00:00	909	ADD-TF-6	47
9625	SS12106		2012-06-16 00:00:00	909	ADD-MLN-ISL4	42
9626	SS12106		2012-06-16 00:00:00	909	ADD-ISL2	48
9627	SN12229	DRY Prot	2012-06-16 00:00:00	1207	DRY-GLN2	12
9628	SN12229		2012-06-16 00:00:00	1800	DRY-GLN2	165
9629	SS12107	NMA Prot	2012-06-18 00:00:00	739	NMA-TF-1	325
9630	SS12108	ADD HEI	2012-06-18 00:00:00	1834	ADD-TF-2	44
9631	SN12230	BPE-HAY2	2012-06-20 00:00:00	1106	BPE-HAY2	0
9632	SN12231	MTR-OKN1	2012-06-22 00:00:00	716	MTR-OKN1	0
9633	SN12232	HEN-CB-292	2012-06-23 00:00:00	1030	HEN-HEP3	60
9634	SN12233	HLY Prot	2012-06-26 00:00:00	2000	HLY-SFD1	35
9635	SS12109	DOB-RFN-IGH2	2012-06-27 00:00:00	659	DOB-RFN-IGH2	0
9636	SS12109		2012-06-27 00:00:00	659	DOB-TF-11	0
9637	SS12110	DOB-RFN-IGH2	2012-06-27 00:00:00	1000	DOB-RFN-IGH2	0
9638	SS12110		2012-06-27 00:00:00	1000	DOB-TF-11	0
9639	SS12111	DOB-RFN-IGH2	2012-06-27 00:00:00	1019	DOB-RFN-IGH2	0
9640	SS12111		2012-06-27 00:00:00	1019	DOB-TF-11	0

9641	SS12112	DOB-RFN-IGH2	2012-06-27	00:00:00	1109	DOB-RFN-IGH2	134
9642	SS12112		2012-06-27	00:00:00	1109	DOB-TF-11	137
9643	SS12113	HWB-PAL2	2012-06-28	00:00:00	454	HWB-PAL2	651
9644	SS12114	ROX-TMH2	2012-06-28	00:00:00	1555	ROX-TMH2	0
9645	SS12114	ROX-TMH1	2012-06-28	00:00:00	1555	ROX-TMH1	192

```
from datetime import timedelta
hvac['Time'] = hvac['Time'].map(lambda x: timedelta(hours = int(str(int(x)).zfill(4)[0:2]), minutes = int(str(int(x)).zfill(4)[2:])))
```

```
hvac.head()
```

	Ident	Flt_Item	Date	Time	Rem_Item	Duration	
0	SS99101	LIV-NSY1	1999-07-02	00:00:00	11:20:00	LIV-NSY1	10
1	SS99101		1999-07-02	00:00:00	11:20:00	NSY-TF-1	20
2	SS99101		1999-07-02	00:00:00	11:20:00	NSY-TF-2	21
3	SS99101		1999-07-02	00:00:00	11:20:00	NSY-ROX1	10
4	SS99102	CML-FKN2	1999-07-02	00:00:00	22:13:00	CML-FKN2	23

```
hvac['DateTime'] = hvac['Date'] + hvac['Time']
```

```
#del hvac['Date']
del hvac['Time']
```

```
hvac.head()
```

	Ident	Flt_Item	Date	Rem_Item	Duration	DateTime
0	SS99101	LIV-NSY1	1999-07-02	00:00:00	LIV-NSY1	10 1999-07-02 11:20:00
1	SS99101		1999-07-02	00:00:00	NSY-TF-1	20 1999-07-02 11:20:00
2	SS99101		1999-07-02	00:00:00	NSY-TF-2	21 1999-07-02 11:20:00
3	SS99101		1999-07-02	00:00:00	NSY-ROX1	10 1999-07-02 11:20:00
4	SS99102	CML-FKN2	1999-07-02	00:00:00	CML-FKN2	23 1999-07-02 22:13:00

```
hvac = hvac.rename(columns={'DateTime':'Start'})
```

```
hvac.head()
```

	Ident	Flt_Item	Date	Rem_Item	Duration	Start
0	SS99101	LIV-NSY1	1999-07-02	00:00:00	LIV-NSY1	10 1999-07-02 11:20:00
1	SS99101		1999-07-02	00:00:00	NSY-TF-1	20 1999-07-02 11:20:00
2	SS99101		1999-07-02	00:00:00	NSY-TF-2	21 1999-07-02 11:20:00
3	SS99101		1999-07-02	00:00:00	NSY-ROX1	10 1999-07-02 11:20:00
4	SS99102	CML-FKN2	1999-07-02	00:00:00	CML-FKN2	23 1999-07-02 22:13:00

```
hvac.Duration = hvac.Duration.map(lambda x: timedelta(minutes=x))
```

```

-----
ValueError                                Traceback (most recent call last)
<ipython-input-44-3c75e160476d> in <module>()
----> 1 hvac.Duration = hvac.Duration.map(lambda x: timedelta(minutes=x))

/usr/local/lib/python2.7/dist-packages/pandas-0.9.1.dev_023b1d4-py2.7-linux-x86_64.egg/pandas/core/series.py
    2007         return Series(new_values, index=self.index, name=self.name)
    2008     else:
-> 2009         mapped = map_f(values, arg)
    2010         return Series(mapped, index=self.index, name=self.name)
    2011

/usr/local/lib/python2.7/dist-packages/pandas-0.9.1.dev_023b1d4-py2.7-linux-x86_64.egg/pandas/lib.so in
<ipython-input-44-3c75e160476d> in <lambda>(x)
----> 1 hvac.Duration = hvac.Duration.map(lambda x: timedelta(minutes=x))

ValueError: cannot convert float NaN to integer

```

```
hvac.Duration = hvac.Duration.fillna(0)
```

```
hvac.Duration = hvac.Duration.map(lambda x: timedelta(minutes=x))
```

```
hvac.head()
```

	Ident	Flt_Item	Date	Rem_Item	Duration	Start
0	SS99101	LIV-NSY1	1999-07-02 00:00:00	LIV-NSY1	0:10:00	1999-07-02 11:20:00
1	SS99101		1999-07-02 00:00:00	NSY-TF-1	0:20:00	1999-07-02 11:20:00
2	SS99101		1999-07-02 00:00:00	NSY-TF-2	0:21:00	1999-07-02 11:20:00
3	SS99101		1999-07-02 00:00:00	NSY-ROX1	0:10:00	1999-07-02 11:20:00
4	SS99102	CML-FKN2	1999-07-02 00:00:00	CML-FKN2	0:23:00	1999-07-02 22:13:00

```
hvac['End'] = hvac.Start+hvac.Duration
```

```
del hvac['Duration']
hvac.head()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 5 entries, 0 to 4
Data columns:
Ident      5 non-null values
Flt_Item   5 non-null values
Date       5 non-null values
Rem_Item   5 non-null values
Start      5 non-null values
End        5 non-null values
dtypes: object(6)
```

```
hvac = hvac.fillna(method='pad')
```

```
hvac.head()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 5 entries, 0 to 4
Data columns:
Ident      5 non-null values
Flt_Item   5 non-null values
Date       5 non-null values
Rem_Item   5 non-null values
Start      5 non-null values
End        5 non-null values
dtypes: object(6)
```

```
hvac['Flt_Item'][1]
```

```
u' '
```

```
hvac=hvac.replace(u' ',nan)
```

```
hvac['Flt_Item'][1]
```

```
nan
```

```
hvac = hvac.fillna(method='pad')
```

```
hvac
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 9646 entries, 0 to 9645
Data columns:
Ident      9646 non-null values
Flt_Item   9646 non-null values
Date       9646 non-null values
Rem_Item   9646 non-null values
Start      9646 non-null values
End        9646 non-null values
dtypes: object(6)
```

```
hvac['Flt_Item'][1]
```

```
u'LIV-NSY1'
```

```
hvac.head(10)
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 10 entries, 0 to 9
Data columns:
Ident      10 non-null values
Flt_Item   10 non-null values
Date       10 non-null values
Rem_Item   10 non-null values
Start      10 non-null values
End        10 non-null values
dtypes: object(6)
```

```
hvac['Delta'] = hvac['End']-hvac['Start']
```

```
hvac.head(10)
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 10 entries, 0 to 9
Data columns:
Ident      10 non-null values
Flt_Item   10 non-null values
Date       10 non-null values
Rem_Item   10 non-null values
Start      10 non-null values
End        10 non-null values
Delta      10 non-null values
dtypes: object(7)
```

```
#set multi-index?
hvac_MI=hvac.set_index(['Ident','Flt_Item','Rem_Item'])
```

```
hvac_MI
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 9646 entries, (SS99101, LIV-NSY1, LIV-NSY1) to (SS12114, ROX-TMH1, ROX-TMH1)
Data columns:
Date      9646 non-null values
Start     9646 non-null values
End       9646 non-null values
Delta     9646 non-null values
dtypes: object(4)
```

```
hvac_MI.head(10)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 10 entries, (SS99101, LIV-NSY1, LIV-NSY1) to (SS99104, CML-FKN1, FKN-TF-2)
Data columns:
Date      10 non-null values
Start     10 non-null values
```

```
End      10 non-null values
Delta     10 non-null values
dtypes: object(4)
```

```
x=hvac_MI.sort(columns=['Delta'], ascending=False)
```

```
x.Delta.head(100)
```

Ident	Flt_Item	Rem_Item	
SS12045	BLN-CAP-4	BLN-CAP-4	69 days, 10:39:00
SS11075	ISL-CB-1422	ISL-CAP-22	69 days, 10:39:00
SS10163	ISL-CB-1422	ISL-CAP-22	69 days, 10:39:00
SS09179	ISL Cable_Conn	ISL-SCM-4	69 days, 10:39:00
SS08168	STK Cable_Conn	STK-CAP-34	69 days, 10:39:00
		STK-CAP-33	69 days, 10:39:00
SN08250	OTA-CB-972	OTA-CAP-4B	69 days, 10:39:00
SN08159	KWA-TF-2	KWA-TF-2	69 days, 10:39:00
SS07146	ISL-SCM-4	ISL-SCM-4	69 days, 10:39:00
SN07207	ALB-CB-902	ALB-CAP-4A	69 days, 10:39:00
SN07185	OTA-CB-972	OTA-CAP-4B	69 days, 10:39:00
SS07022	ISL-CB-332	ISL-CAP-14	69 days, 10:39:00
SN07006	OTA-DS-974	OTA-CAP-4A	69 days, 10:39:00
		OTA-CAP-4B	69 days, 10:39:00
SN04310	WIL-TF-3	WIL-TF-3	69 days, 10:39:00
SN04230	OTA-REA-4A	OTA-CAP-4A	69 days, 10:39:00
SN03093	HEN-CB-912	HEN-CAP-5B	69 days, 10:39:00
SS03048	STK-TF-9	STK-TF-9	69 days, 10:39:00
SS02076	ISL-SCM-5	ISL-SCM-5	69 days, 10:39:00
SS01139	ISL-SCM-4	ISL-SCM-4	69 days, 10:39:00
SN01331	OTA-REA-29	OTA-CAP-29	69 days, 10:39:00
SN99162	ALB-DS-904	ALB-CAP-4A	69 days, 10:39:00
SS12030	HWB-TF-2	HWB-TF-2	68 days, 19:31:00
SS11197	ADD-TF-7	ADD-TF-7	66 days, 11:30:00
SN09025	PEN-TF-8	PEN-TF-8	64 days, 23:24:00
SS10139	ISL-SCM-5	ISL-SCM-5	64 days, 0:37:00
SN08327	ALB-TF-4	ALB-TF-4	63 days, 1:45:00
SN04176	OTA-CB-922	OTA-CAP-2A	61 days, 17:02:00
SN10801	LTN-TF-2	LTN-TF-2	61 days, 5:58:00
SS04019	STK-SCM-1	STK-SCM-1	56 days, 10:30:00
SN11108	WRK-TF-30	WRK-TF-30	54 days, 1:23:00
SN08058	HEN-CB-312	HEN-HEP4	50 days, 19:46:00
SS03116	BRY HEI	BRY-CAP-4A	47 days, 14:21:00
SS11046	BDE-CB-17	BDE-CAP-1	46 days, 7:01:00
SN01190	HWA-SFD1 Sys_Conditi	HWA-TF-1	42 days, 0:13:00
SS07128	ISL-TF-3	ISL-SVC-3	33 days, 15:40:00
		ISL-TF-3	33 days, 15:40:00
SS99144	ISL-SCM-5	ISL-SCM-5	32 days, 23:54:00
SS10174	KIK-SVC-2A	KIK-SVC-2A	30 days, 3:01:00
SS11012	BLN-CAP-4	BLN-CAP-4	26 days, 17:15:00
SN07185	OTA-CB-972	OTA-CAP-4A	26 days, 11:19:00

SS02205	ISL Cable_Conn	ISL-SCM-4	25 days, 19:23:00
SN12044	WTU-CB-1102	WTU-TF-4	24 days, 12:05:00
		RDF-WTU1	24 days, 11:17:00
SNO1403	KOE HEI	KOE-CAP-3	24 days, 4:55:00
SN08159	KWA-TF-2	KWA-WIL2	23 days, 23:26:00
SNO9133	TNG HEI	TNG-TF-LS1	23 days, 21:02:00
SNO5800	ALB Cable_Conn	ALB-CAP-C4B	22 days, 23:53:00
SN07825	MDN-TF-2	MDN-TF-2	18 days, 6:36:00
SS10094	KIK C&I	KIK-SVC-2B	18 days, 0:59:00
SN09078	WWD Prot	MHT-WWD2	17 days, 6:36:00
SS04148	TWZ Prot	TWZ-TF-18	16 days, 10:10:00
SS11038	BRY-CB-39	BRY-TF-4	16 days, 6:37:00
SN11362	OTA-CB-1422	OTA-CAP-30	15 days, 22:29:00
SN04244	BRK-BPE2	BRK-BPE2	14 days, 9:09:00
SS11079	ISL-SVC-9	ISL-SVC-9	14 days, 7:57:00
SS10145	ISL Stn_Serv	ISL-SVC-9	14 days, 4:07:00
SN04080	OTA-CB-492	OTA-TF-12	13 days, 0:41:00
SS11151	GOR-TF-3	GOR-TF-3	11 days, 23:10:00
SS12105	ASB-VT-1	ASB-TF-1	11 days, 21:27:00
SN02805	OTA-CAP-4A	OTA-CAP-4A	11 days, 19:24:00
SS04081	STK-CB-1242	STK-CAP-7D	11 days, 11:52:00
SN07194	TNG Prot	TNG-TF-11	11 days, 3:55:00
SN06128	HEN-TF-ET3	HEN-TF-3	10 days, 23:21:00
		HEN-TF-ET3	10 days, 23:21:00
SS04059	STK-CB-1242	STK-CAP-7D	10 days, 22:07:00
SN00225	HEP-DS-184	HEN-HEP4	10 days, 17:55:00
SS00176	BDE-CAP-1	BDE-CAP-1	10 days, 17:10:00
SN08113	OTA-CAP-4B	OTA-CAP-4B	10 days, 5:53:00
SN09289	HAY HVDC	HAY-TF-2	10 days, 0:34:00
SS12022	HWB-TF-4	HWB-TF-4	9 days, 23:52:00
SN05090	EDG-OWH1	EDG-OWH1	9 days, 4:30:00
SN11144	WKO-CB-292	WKO-TF-2	9 days, 3:40:00
SS11029	BRY-TF-2	BRY-TF-2	9 days, 2:23:00
SN04278	MTM-CB-312	MTM-CAP-1	8 days, 21:19:00
SN07005	SVL-TF-1	SVL-TF-1	8 days, 20:37:00
		ALB-SVL1	8 days, 20:25:00
SS06192	IGH-RFN2	IGH-RFN2	8 days, 5:08:00
SN11185	OKI-CB-302	NAP-OKI2	8 days, 1:37:00
SN03339	CPK-TF-3	CPK-TF-3	8 days, 1:28:00
SN05132	BPE-HAY2	BPE-HAY2	7 days, 23:03:00
SN08399	RDF-TF-LS1	RDF-TF-LS1	7 days, 22:46:00
SS11055	BLN-CAP-4	BLN-CAP-4	7 days, 21:45:00
SN04209	TMU-TF-2	TMU-TF-2	7 days, 18:41:00
SN02217	OTA-CAP-4A	OTA-CAP-4A	7 days, 16:37:00
SS07062	ASB-VT-3	ASB-TF-3	7 days, 15:43:00
SNO1190	HWA-SFD1 Sys_Conditi	HWA-TF-1	7 days, 15:38:00
SN10141	TMN Cust_Fault	TMN-TF-5	7 days, 13:36:00
SN04244	BRK-BPE1	BRK-BPE1	7 days, 12:53:00
SNO7069	ALB-CAP-1	ALB-CAP-1	7 days, 11:08:00
SNO2201	PEN-CAP-1	PEN-CAP-1	7 days, 11:06:00
SNO1027	OTA-CB-5812	OTA-CAP-29	7 days, 10:07:00
SS01060	ISL-SCM-5	ISL-SCM-5	7 days, 8:07:00

```

SS03053 KAI Cable_Conn      KAI-TF-2      7 days, 8:03:00
SNO6095 ALB-CB-912         ALB-CAP-4B    7 days, 4:07:00
SS01155 AHA-OTI2          AHA-OTI2      7 days, 0:28:00
SNO9075 KIN HEI           KIN-TF-4      6 days, 21:19:00
SNO7171 OTA-CAP-12        OTA-CAP-12    6 days, 18:19:00
SN10259 FHL-WPW2          KWA-WIL2      6 days, 17:33:00
SNO2380 OTA Cable_Conn    OTA-CAP-2A    6 days, 15:15:00
Name: Delta, Length: 100

```

```

#get transformers?
import re

def str_match(pattern,string):
    match = re.search(pattern, string)
    # If-statement after search() tests if it succeeded
    if match:
        return string
    else:
        return nan

```

```
hvac['TX']=hvac.Flt_Item.map(lambda x: str_match('-TF-',x))
```

```

hvac

<class 'pandas.core.frame.DataFrame'>
Int64Index: 9646 entries, 0 to 9645
Data columns:
Ident      9646 non-null values
Flt_Item   9646 non-null values
Date       9646 non-null values
Rem_Item   9646 non-null values
Start      9646 non-null values
End        9646 non-null values
Delta      9646 non-null values
TX         497 non-null values
dtypes: object(8)

```

Ok, try and get the following:

1. number of recorded forced outages per year
2. forced outage minutes per year?
3. most unreliable kit
- 4.

```

#Ok, define some grouping functions and start to try and pull some stats to plot
def by_year(data):
    x = data.groupby(lambda x: x.year)

```

```

    return x
def by_month(data):
    x = data.groupby(lambda x: x.month)
    return x
def by_week(data):
    x = data.groupby(lambda x: x.week)
    return x
def by_day(data):
    x = data.groupby(lambda x: x.timetuple().tm_yday) #get day of year
    return x

```

```

#group by event
by_id = hvac.groupby('Ident')

```

```

#group by year
byyear=hvac.groupby(hvac['Start'].map(lambda x: x.year))

```

```

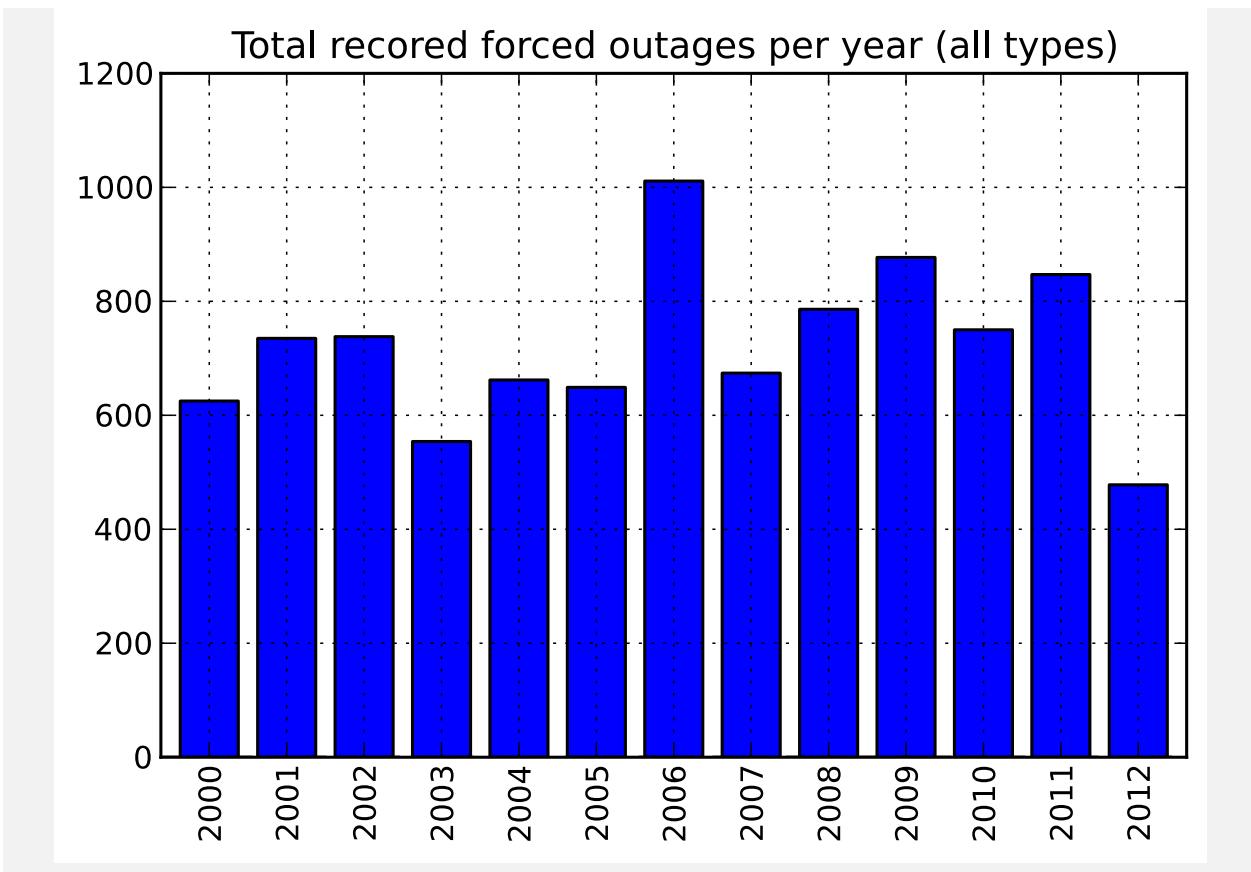
plt.figure(1)
x={}
#total outages per year
for year, yeardata in byyear:
    print year, len(yeardata.Flt_Item)
    x[year] = len(yeardata.Flt_Item)
total_outages=Series(x)
total_outages[1:].plot(kind='bar', title='Total recorded forced outages per year (all types)')

```

```

1999 260
2000 625
2001 735
2002 738
2003 554
2004 662
2005 649
2006 1011
2007 674
2008 786
2009 877
2010 750
2011 847
2012 478
<matplotlib.axes.AxesSubplot at 0x4737750>

```



```
total_outages[1:].describe()
```

Stat	Value
count	13.000000
mean	722.000000
std	140.498517
min	478.000000
25%	649.000000
50%	735.000000
75%	786.000000
max	1011.000000

```
plt.figure(2)
#Transformers per year
x={}
for year, yeardata in byyear:
    print year, len(yeardata.TX[yeardata.TX.notnull()])
    x[year] = int(len(yeardata.TX[yeardata.TX.notnull()]))
x = Series(x)
x[1:].plot(kind='bar', title='Recorded transformer forced outage per year')
```

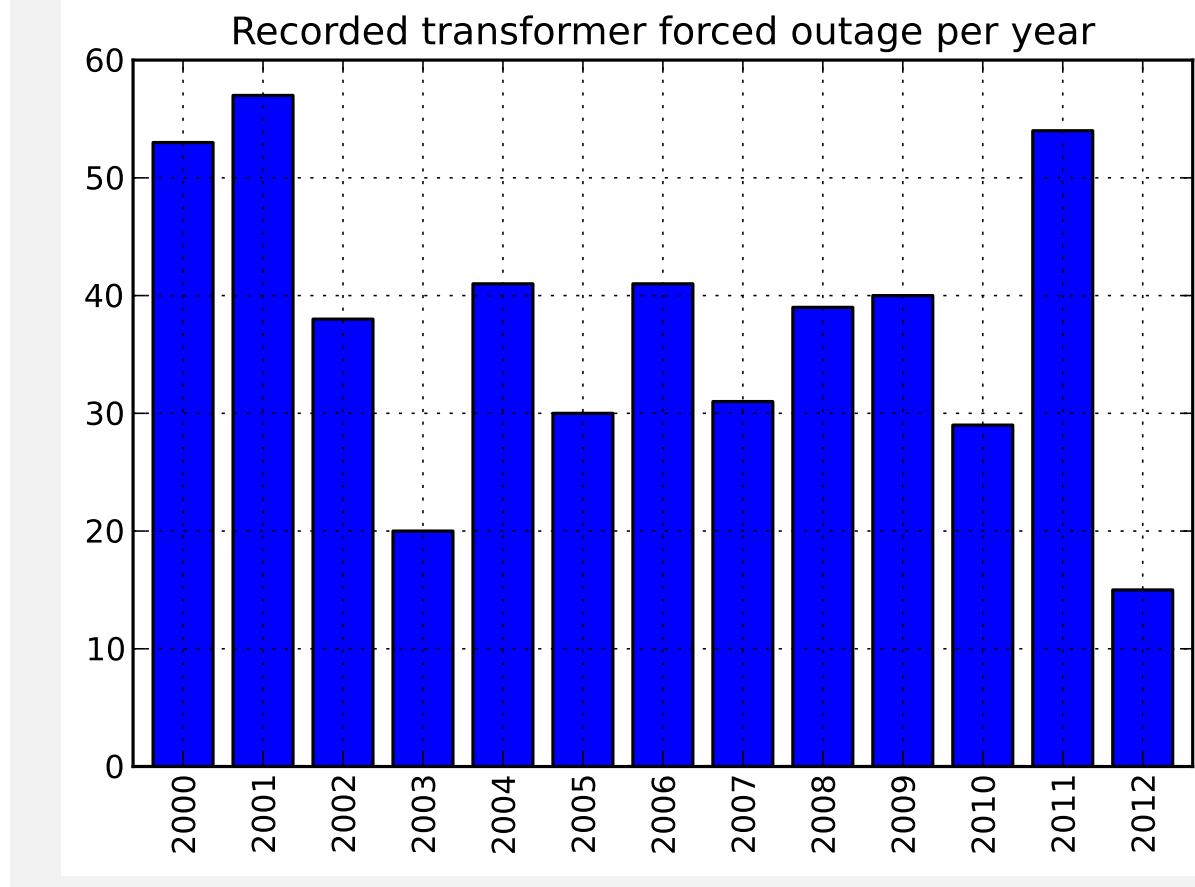
```
1999 9
2000 53
2001 57
```

```

2002 38
2003 20
2004 41
2005 30
2006 41
2007 31
2008 39
2009 40
2010 29
2011 54
2012 15

```

<matplotlib.axes.AxesSubplot at 0x4d82350>



```

#Forced outage minutes per year (all types)
x={}
for year,yeardata in byyear:
    print year,sum(yeardata.Delta)
    x[year] = sum(yeardata.Delta)
x = Series(x)
#x.plot(kind='bar',title='Total forced outage time per year')
#x[0:1].day

```

```
1999 140 days, 4:54:00
2000 120 days, 14:57:00
2001 314 days, 18:10:00
2002 197 days, 14:29:00
2003 272 days, 13:09:00
2004 466 days, 14:21:00
2005 154 days, 21:04:00
2006 225 days, 19:45:00
2007 707 days, 4:02:00
2008 536 days, 5:35:00
2009 343 days, 15:14:00
2010 430 days, 14:59:00
2011 539 days, 17:59:00
2012 293 days, 14:45:00
```

```
for year,yeardata in byyear:
    print year,yeardata.Flt_Item.count()
```

```
1999 260
2000 625
2001 735
2002 738
2003 554
2004 662
2005 649
2006 1011
2007 674
2008 786
2009 877
2010 750
2011 847
2012 478
```

```
for fault_item in unique(hvac.Flt_Item):
    print fault_item
```

```
LIV-NSY1
CML-FKN2
CML-FKN1
OPK-KPI-SFD2
CYD-CML-TWZ2
CYD-CML-TWZ1
MTI-WKM2
ADD-TF-6
WES HEI
OAM-WTK1
CBE-TF-1
MTI HEI
ISL-SVC-1
TKR-WIL2
```

```
KAW Cust_Fault
HBK-HOR1
COB-UTK1
OPK-SFD1
DVK-WPW1
EDG-WAI1
KIN-LFD-TRK2
ANA-DS-1041
GIS-TOB1
ALB-DS-904
ISL-TF-2
OTA-WKM1
ARI-MER1
HEN-MPE2
HEN-MPE1
ROT-CB-15
STU-TIM1
BOB-WES-HAM1
HWB-ROX1
BLN-STK1
RPO-WRK1
WPW-DVK-WDV2
EDN-INV1
TNG HEI
OPK-TF-4
HAM 220kV Bus
BPE-MH01
OTA-WKM2
NMA Unknown
HAM-TF-5
ARI-KIN2
GIS-TF-1
DVK HEI
MAN-NMA2
MAN-NMA1
NMA-CAP-3
TKU Gen_Fault
KAW-OHK1
MOT-DS-64
BAL-GOR1
TIM HEI
TMN Cust_Fault
EDG-KAW2
HEP-CB-252
WPW-DVK-WDV1
ONG HEI
BRY-CB-62
NMA-CAP-1
FHL-TUI1
TIM-DS-113
HWB-PAL2
ROT-VT-25
```

PEN-CB-2072  
KAW-CT-102  
PEN-VT-1792  
HWA 110kV Bus  
MST Cust\_Fault  
ISL-SCM-5  
NMA Gen\_Fault  
KWA-WIL1  
KPU-WKO2  
TKA-TIM1  
OKI-TF-31  
TIM-DS-43  
NSY-ROX1  
SFD HEI  
TKH-WAI1  
KOE-KTA2  
KTA Stn\_Serv  
NMA-TMH2  
UHT-DS-87  
WTU-DS-854  
BPE-TNG1  
TNG Cust\_Fault  
SWN HEI  
KAW-CB-582  
WIL HEI  
MPE Prot  
NPK Prot  
FHL C&I  
TUI Gen\_Fault  
BPE Cust\_Fault  
OKN-NPK-ONG1  
ARI-PAK1  
MLG HEI  
ATI-DS-116  
TWI HEI  
HLY-TMN1  
MRR-TF-1  
ATI-MTS1  
NMA C&I  
PEN-CAP-1  
EDG-OKE1 HEI  
NMA Cust\_Fault  
HEN Prot  
RDF-WRK1  
RDF-WHI1  
IGH-MCH-KIK1  
HLY-SFD1  
ALB-HEN2  
STK-DS-276  
GIS-TUI2  
GIS-TUI1  
BAL-HWB1

ALB Sys\_Conditions  
NMA-TMH1  
MTS-TF-11  
BEN-CB-582  
MTM Cust\_Fault  
ONG-DS-84  
TKR Prot  
INV-ROX2  
KPO-TMU1  
MNG HEI  
NMA HEI  
BRY HEI  
ISL-LIV1  
OAM-STU-WTK2  
BPE-WDV2  
BOB-WIR-OTA1  
OTA Prot  
WRK-WHI1  
CST-DS-146  
TKU-WKM2  
ARI-HTI1  
CPK-TF-1  
NPL-CB-262  
NMA-TMH1 HEI  
SFD-TF-10  
WTK Comms  
COL-HOR2  
DOB-IGH1  
COL HEI  
GYM-KUM1  
HWA Surge\_Arr  
DOB-TF-2  
BPE-MTR-OKN1  
ARI Comms  
GOR-ROX1  
ROX-TMH1  
INV Prot  
OTA-CAP-12  
TKR-DS-347  
TKR-DS-327  
STK-MOT-UTK1  
OTI Prot  
WAI-TF-3  
ASY-WPR1  
COL Cust\_Fault  
WHI Cable\_Conn  
BRY-REA-1  
PAK HEI  
FHL-WPW1  
BEN-TWZ1 HEI  
MTM-TGA-TMI1  
KIN-CB-32

MTR-DS-56  
EDG 110kV Bus  
EDG Prot  
TGA Prot  
INV-MAN2 HEI  
NMA Prot  
HWB-PAL1  
PRM-CVT-102R  
UHT-DS-66  
HLY-SFD1 HEI  
TKU-TF-21  
TKU Stn\_Serv  
OTA-CB-82  
OTA-CAP-11  
HAM HEI  
FHL-WPW2  
ISL-KIK1  
BRK HEI  
ARI-HTI-ONG1  
OHA-TWZ2 Prot  
OHA-TWZ1 Prot  
GYM-CAP-2  
WRA HEI  
MLG-TF-2  
BRK Prot  
KWA-DS-56  
KAI-SBK2  
TUI-TF-10  
SPN-TF-LS1  
WRK HEI  
TMK-TIM1  
HWB-ROX2  
OKE-TMI1 HEI  
ALB-CB-202  
ISL Prot  
OHA HEI  
WTN HEI  
NPL Prot  
PEN HEI  
ASB-TIM-TWZ1  
ISL-TKB1  
WHI HEI  
HEN HEI  
CYD-CML-TWZ1 Prot  
AHA-OTI2  
ISL-SBK2  
BPE-HAY1  
MST-GYT-UHT2  
MST-GYT-UHT1  
TKU-WKM1  
TRK-TGA1  
WHI Cust\_Fault

KOE-KTA1  
CUL-KKA1  
ROX Scada  
ARI-HAM1  
KUM-OTI1  
MGM-MST1  
TKA Prot  
RPO-CB-532  
OTA HEI  
WEL Prot  
BLN-ARG-KIK1  
HWA-VT-1  
TUI HEI  
KIK-STK3  
PRM-PNI-TKR1  
SWN Prot  
HEN-HEP3  
TMU-TF-2  
ISL-SBK1  
CST-TF-1  
APS Cust\_Fault  
COL-OTI2  
COL-OTI1  
WAI-TF-4  
MST 110kV Bus  
HAY-DS-1004  
IGH-WMG-WPT1  
TUI-WRA2  
WHU Prot  
COL-HOR2 HEI  
WAI-DS-66  
GFD-HAY1  
BPE-LTN-WIL1  
BPE-LTN-HAY3  
SFD Prot  
OKI-WRK3  
WRK Stn\_Serv  
PEN Prot  
MAN 220kV Bus  
UHT-TF-1  
OTA C&I  
HAM Prot  
EDG-TRK2  
EDG-TRK1  
ROX HEI  
EDG-OWH1  
WGN-TF-1  
MHO-DS-294  
PNI 33kV Bus  
BPE Prot  
KIN-LFD-TRK1  
ONG-TF-1

HEN C&I  
HWB-PAL2 HEI  
ISL-CB-352  
BPE HEI  
ARI-ANA1  
TMK-TIM2  
HEN-CAP-1  
EDG-OKE1  
RDF-TUI1  
RDF-TUI2  
TUI-WRA1  
KHU-DS-274  
BRK-SFD2  
BRK-SFD1  
WMG Prot  
IGH-KIK2  
PAP-TF-2  
TIM-TF-4  
HEN-HEP2 HEI  
MGM-TF-3  
MGM-TF-2  
MGM Prot  
LTN-TF-2  
BPE-MTN-WGN2  
OAM Prot  
ADD-ISL4  
MAN HEI  
PRM-DS-204  
INV-DS-725  
PAK Unknown  
WRK-DS-105  
KAW-CB-632  
DAR-TF-1  
WGN Scada  
BDE-EDN1  
MST-DS-57  
OHC Gen\_Fault  
NPL-TF-7  
BDE-CAP-1  
HAY C&I  
OTA-CAP-4B  
PRM-PNI-TKR2  
WKM HEI  
OTA Unknown  
KIN Prot  
COB HEI  
DAR-MPE1  
MPE-CB-132  
ROX-TMH2  
HEP-CB-182  
COL-TF-6  
INV-DS-616

HEP-DS-184  
DAR HEI  
BLN Prot  
ALB-CAP-1  
STU Prot  
OWH-TRK1  
BPE-TKU2  
OKE-TRK1  
OKE-TMI1  
SFD-TMN1  
TMN Prot  
WRK Prot  
RPO-TNG1  
ISL-SVC-3  
ISL-CAP-14  
BEN-TF-2  
TMN-TF-8  
SFD-DS-167  
ROX Prot  
CPK-TF-2  
HLY Prot  
WTU Cust\_Fault  
PEN C&I  
HTI C&I  
TKR-CB-92  
ASY-ISL1  
ISL-TIM-TWZ1  
AVI Prot  
ALB-HEN1  
CYD-ROX2  
ATI-TRK1  
ATI-CB-102  
ARI-TF-9  
BPE-TKU1  
HEN-LT-456  
MAN-NMA3  
INV-MAN2  
OTI HEI  
WIL-TF-8  
PEN-CB-732  
OTI-TF-6  
MHO-PRM1 Unknown  
ALB HEI  
HOR-TF-5  
BOB-TF-2  
ROT Prot  
NMA 220kV Bus  
OTA-CB-5812  
ONG-CB-82  
CML HEI  
TRK-TF-1  
KAW-CB-52

OTA-PEN5  
SFD-TF-6  
ARG-KIK1  
TAK HEI  
MCH HEI  
SBK Cust\_Fault  
HAM-CBG-KP02  
BAL-BWK1  
CUL Prot  
ONG-CB-162  
OWH-TF-2  
WKM Prot  
ROT-CB-322  
NPL-DS-257  
MTO-CB-1292  
AVI Gen\_Fault  
HAM Cust\_Fault  
WRK Cust\_Fault  
WRK-CB-1082  
IGH-KIK2 HEI  
WTK Prot  
ATI Gen\_Fault  
ATI HEI  
BLN-DS-2139  
ISL-KIK3  
ABY-TF-2  
GIS Prot  
ARI-HAM2  
KOE Prot  
KOE-CB-1192  
KOE C&I  
CPK-VT-16  
SDN HEI  
LIV HEI  
WHI-CB-8  
MGM Cust\_Fault  
STK-SCM-1  
ATI-OHK1  
WRA Prot  
KAW-TF-2A  
WPW HEI  
WPW-TF-2  
MNI HEI  
ISL-CAP-25  
KEN Prot  
OHK Gen\_Fault  
WKO-CB-512  
ASB Cust\_Fault  
HEP-DS-244  
MLG Prot  
KTA-TF-5  
KTA-TF-4

KTA-CB-242  
RDF-TF-1  
TRK Prot  
MTM Prot  
IGH-WMG-WPT2  
BPE-MH02  
ISL-PAP2 Prot  
KAW Prot  
HEN Sys\_Conditions  
TMU Unknown  
ARI-KIN1  
HEN-TF-5  
ROS C&I  
BOB-WES-HAM2  
KIK-DS-126  
ARI-MTS1  
PRM-TF-3  
KAW Unknown  
MHO-PRM1  
ISL C&I  
HLY-TAK-OTA2  
TKB HEI  
CYD-ROX1  
AHA HEI  
ISL-DS-333  
BPE-MTR1 HEI  
STK-DS-234  
KTA-VT-12  
ISL-CB-332  
HEP-DS-196  
FHL-TUI1 HEI  
MHO Prot  
ISL-CAP-22  
CPK-VT-10  
MAN-NMA2 HEI  
PRM-LT-102R  
OPK-CVT-3  
WIL Sys\_Conditions  
HWA-SFD1 Sys\_Conditi  
WPT-CB-39  
ROS-DS-54  
MGM Sys\_Conditions  
CPK-WIL1  
WIL-CB-202  
KWA HEI  
TMH-DS-576  
HWA-VT-2  
HEN-DS-244  
KOE HEI  
NPK-TF-ET1  
OKN-NPK-ONG1 HEI  
OPK-TF-5

AHA-CB-122  
MNG-DS-224  
ROT-DS-367  
MHO-DS-44  
TRK-DS-227  
WRK-DS-126  
ATI-DS-84  
ATI-CB-82  
BOB-DS-84  
NPL-SFD2  
NPL-SFD1  
WHU-WKO2  
WHU-WKO1  
TKR-DS-184  
ROT-CB-362  
HOR Prot  
HAM-WHU1  
PEN-DS-804  
PEN-DS-784  
MNG-DS-227  
BPE-WDV1  
UHT Prot  
DVK Prot  
HIN-KPO1  
INV-ROX1 HEI  
MHO-PRM2  
ANA-CB-1072  
HOR-TF-8  
ABY-TKA1  
AHA-CB-82  
KKA Prot  
UHT-DS-84  
ISL Unknown  
KEN-MPE1  
EDG-TMI-TRK1  
STK Prot  
OTA-REA-29  
DVK-TF-2  
AHA Prot  
WTU-TF-3  
EDG-KAW3  
MPE Unknown  
BOB-MER2  
EDG-WAI21  
ISL-SCM-4  
HWB-TF-4  
HUI HEI  
ALB-VT-11  
WRA-TF-1  
OTI 11kV Bus  
BRY Prot  
ROS 110kV Bus

MGM-WDV1  
BOB HEI  
PAL-DS-94  
ARI-MER1 HEI  
ATI-CB-112  
WPR Prot  
GLN-HLY1  
WES 110kV Bus  
ROS HEI  
ROS-CB-62  
MAT Prot  
ARI-DS-284  
MAN-NMA1 HEI  
RDF-CB-82  
BRY-REA-5  
ATI-CB-132  
AHA-KUM1  
CPK-WIL3  
WGN-WVY1  
WGN-CB-42  
DOB-GYM1  
LIV Prot  
IGH Prot  
ASB-BRY1  
SBK-WPR1  
WPW Prot  
COB-MOT-STK2  
MTR-TF-2  
BPE-MTR1  
BPE-HAY2  
HAM-HLY1  
HEP-DS-237  
GIS-CAP-1  
BEN-DS-521  
GYM Prot  
BAL HEI  
BPE-TF-2  
INV HEI  
STK Scada  
ALB Cust\_Fault  
MNI-SFD1  
CST-SFD2  
NSY-CB-242  
ISL-CAP-C22  
SPN-CB-1172  
MTI-WKM1  
MNG-DS-286  
DOB Prot  
TNG-TF-11  
HAY HVDC  
SFD-CB-1112  
WKM Unknown

NSY-ROX1 HEI  
STK-CB-6  
EDG-WAI1 HEI  
AVI-CB-112  
BPE-MTN-WGN1  
BRK-BPE2  
HWA-SFD1  
HAY HEI  
OHK-DS-96  
OTA-DS-233  
ADD HEI  
ISL HEI  
TRK-DS-586  
WRK-DS-196  
WRK-CB-192  
ISL Scada  
WPR HEI  
RPO HEI  
NPL-TF-8  
ASB HEI  
HWB 33kV Bus  
KAW-DS-124  
CST-MNI1  
OWH-VT-5  
HAM-WHU2  
ARA Prot  
RDF-TF-2  
MDN-CB-452  
NCC HEI  
TMU Prot  
ASB-VT-8  
ABY Prot  
COL-HOR3  
ARI-BOB1  
GLN-DS-1483  
FKN-TF-2  
CML Prot  
OTA-CAP-4A  
WRK-PPI-WKM1  
ROT-DS-357  
TMU-TF-1  
MOT-DS-77  
HKK Scada  
MTM-TF-1  
TNG-DS-316  
OKN-DS-96  
KPU HEI  
EDG-CB-142  
PRM-DS-84  
DAR-MPE2  
COL-CB-272  
TNG-TF-3

KAI HEI  
ROT HEI  
PAP-TF-3  
HWB-PAL1 HEI  
WPR-CB-142  
ADD-ISL4 HEI  
TGA HEI  
KAW-TF-1  
MNG-ROS2  
OHK HEI  
HKK-OTI2  
KPO-TMU1 HEI  
TKR-DS-304  
MHO Cust\_Fault  
HOR-ISL2  
HKK-KUM1  
ADD-CB-52  
MGM-DS-174  
ADD-CB-592  
KIK-STK1  
TWZ Prot  
WTK C&I  
GYT Cust\_Fault  
KOE-MPE2  
KOE-MPE1  
TMH Prot  
BPE-TF-1  
OAM Scada  
EDG HEI  
WPI Gen\_Fault  
BPE Comms  
EDG-DS-326  
HEN-CAP-5B  
ISL Cable\_Conn  
MGM HEI  
HAY Cable\_Conn  
GLN HEI  
CBG HEI  
OHA-CT-702  
KWA Prot  
OTA-CT-92  
BOB-MER5  
OTA-TF-2  
OTA Cable\_Conn  
NSY-TF-1  
MTI Prot  
HLY-TMN1 HEI  
EDG-CVT-1  
BRB HEI  
TWZ-CVT-2  
OTA-CB-272  
BLN-VT-2067

MTI-CB-112  
CST-TF-4  
TRK-CB-122  
CML 33kV Bus  
MTO HEI  
HWB-CB-282  
MTO Cust\_Fault  
WRK C&I  
MNG 110kV Bus  
CUL-WPR1  
OTA Comms  
MPE Stn\_Serv  
EDG-CB-252  
OKI HEI  
DVK Stn\_Serv  
EDN Cust\_Fault  
HEN-CB-3222  
TMH-CVT-11  
MOT Prot  
HWB-DS-205  
ISL-CB-542  
OTA-CB-302  
SBK-TF-2  
STK-TF-9  
MNG-CB-2338  
HWB-TF-5  
MLG C&I  
KAI Cable\_Conn  
BLN-DS-74  
HEN-CB-912  
BDE-GOR1  
TRK-CB-342  
WRK Comms  
HWA HEI  
ISL-DS-566  
OHA-TWZ2  
OHA-TWZ1  
OTA-CB-922  
WPW Cust\_Fault  
HEN-HEP1  
OAM HEI  
ARI-CB-152  
WHI-DS-587  
TIM Comms  
WRK Unknown  
OTI Scada  
BRK-DS-1107  
TMI-OWH-TRK1  
WPA HEI  
HAY Prot  
ALB Prot  
MST Prot

OWH-TF-1  
HOR-CB-1272  
MNI Comms  
PNI-CB-222  
KAW Cable\_Conn  
WKM 220kV Bus  
PAK C&I  
OKI-DS-235  
KIK-STK3 HEI  
WTU-DS-1033  
TMK Prot  
ALB-CB-912  
BEN HVDC  
BOB-CB-292  
OTA-CB-262  
WIR Prot  
MTM-DS-67  
HEN-CB-412  
MPE-CB-252  
FHL Prot  
WIL-CB-392  
KAW-DS-597  
BLN HEI  
HEP-ROS1  
KPU-WKO1  
OKN-CB-92  
HWA-WVY1  
ISL-CB-1492  
AVI HEI  
SFD-CB-162  
APS-DS-126  
CLH-OTI1  
HUI-MNI1  
KAW-DS-174  
DOB HEI  
COL Prot  
MHO HEI  
KAW-DS-64  
BPE-DS-533  
BPE-DS-555  
HTI HEI  
ROT-TF-4  
NPK-CB-232  
PAP Prot  
NPL HEI  
CPK-VT-2  
MTM HEI  
OTC-DS-884  
HOR-CB-72  
DVK-CB-37  
PAP HEI  
CPK-TF-4

TMN-TF-5  
CPK-DS-74  
CPK-TF-3  
KPO Comms  
HEP-CB-202  
HEP HEI  
HOR-CT-142  
ISL 66kV Bus  
WVY Prot  
HAM-CT-442  
HWA Gen\_Fault  
FHL-DS-159  
NPL-CB-222  
HEN Unknown  
STK HEI  
GIS-DS-234  
BRY-ISL1  
HWA-TF-2  
SFD 110kV Bus  
HOR-ISL1  
MRA Cust\_Fault  
ROS-CB-172  
UHT Cable\_Conn  
TKR-WIL1  
WDV-CB-9  
OTA-CB-492  
OHB-CB-802  
MNG Prot  
CUL-CB-142  
DVK-WPW-FHL2  
MAN-DS-276  
MDN-TF-1  
MHO-TF-3  
WVY Unknown  
WKO Prot  
MDN-CVT-45  
GOR-CB-282  
KAW-CB-622  
TMH-DS-605  
WEL-TF-1  
BRK-CVT-12  
HAM-CBG-KPO1  
WEL Cust\_Fault  
KKA Unknown  
APS HEI  
HKK Comms  
OTI Comms  
WRK-DS-194  
MDN-MPE1  
MDN HEI  
EDG-WAI2  
KAW HEI

MTN-CB-42  
KPO HEI  
STK-CB-1242  
CYD HEI  
WGN Prot  
HAY-CB-552  
HUI-CB-862  
SVL Prot  
ASB Scada  
ASB-CB-1102  
SFD-LT-534  
MRA Stn\_Serv  
PAL-CB-212  
MTN HEI  
SBK HEI  
KWA Cust\_Fault  
KOE-CB-162  
ABY Unknown  
WPR-CB-102  
EDG-TF-8  
TRK-DS-147  
HLY-CB-402  
TRK-DS-197  
BLN-KIK1  
SFD-CVT-31  
SFD Gen\_Fault  
IGH-WPT1  
OHC Scada  
WPT-TF-1  
OTA-REA-4A  
NMA-TF-2  
WDV HEI  
BRY-CAP-5A  
BRK-BPE1  
HWA Sys\_Conditions  
KPI Gen\_Fault  
MTM-CB-312  
OPK-LT-525  
MST-UHT2  
MST-UHT1  
SVL HEI  
OTA-WKM3  
ADD-DS-124  
HTI Prot  
MNI Cust\_Fault  
WPW-DVK-WDV2 HEI  
KIN-TF-2  
TMU-DS-54  
TMU-DS-44  
ROS Prot  
KIN C&I  
ISL-KIK3 HEI

SBK-WPR1 HEI  
ASY-WPR1 HEI  
OAM-WTK2  
MTM-CAP-1  
TWZ-CB-2672  
WHU Sys\_Conditions  
COB Prot  
LIV-WTK1  
GYM-CB-5  
WIL-TF-3  
ASY Prot  
BOB-HAM1  
HAY-CB-192  
TKH-WAI1 HEI  
HTI-DS-114  
IGH Comms  
PAL Prot  
INV-TWI1  
ARI-HTI1 HEI  
BDE HEI  
WTK Scada  
KEN-TF-1  
HOR-DS-76  
SPN Prot  
ALB Cable\_Conn  
DAR-TF-2  
MOT-TF-6  
HKK-KUM1 HEI  
COB Comms  
OTA-DS-245  
ROT-DS-354  
WHI C&I  
OKN HEI  
HAY-DS-245  
OPK-SFD2  
MPE-TF-1  
PEN-TF-10  
NPK Scada  
ARI Prot  
WRK Gen\_Fault  
ADD-ISL2  
OTA-WKM2 HEI  
RPO Comms  
ADD-ISL3  
HEN Scada  
MTM-TRK1  
SFD Comms  
CPK Prot  
WIR-DS-666  
STK C&I  
MST-CB-312  
TWZ Cust\_Fault

GFD-HAY2  
TMK-CVT-132  
ISL-SPN2  
ISL-SPN1  
CUL HEI  
ISL-CB-982  
HUI-CB-822  
KIN-TF-1A  
OHK-CB-102  
WKO-TF-2  
WHU-TF-1  
ADD-VT-28  
EDG-TF-5  
BLN-CAP-4  
BWK Gen\_Fault  
ROS-TF-4  
RPO Prot  
HAY-TKR2  
HAY-TKR1  
SFD Cable\_Conn  
TMN HEI  
FKN Comms  
WRK Cable\_Conn  
CPK Sys\_Conditions  
NPK-DS-76  
PAK-DS-1654  
HAM-TF-2  
BRB-VT-22  
BDE-DS-127  
DAR-DS-57  
WHI-DS-527  
WPW-CB-222  
BDE-DS-107  
BDE Unknown  
MPE-DS-1394  
BEN Gen\_Fault  
LTN-TF-3  
OTA Stn\_Serv  
OTA-CB-252  
HOR 66kV Bus  
HLY-TWH1  
WVY-TF-2  
KAI-SBK1  
DOB-IGH1 HEI  
MST HEI  
MST Scada  
HTI-TF-2  
PEN-VT-13  
EDG-KAW1  
HAY-UHT2  
BRY-CAP-6A  
TWH-DS-416

TWZ 33kV Bus  
HEP Prot  
CPK HEI  
WAI C&I  
BEN Prot  
ASB Prot  
TMN-TWH1  
TWH Scada  
OWH-TMI-TRK1  
WPT-VT-1  
STK Cable\_Conn  
PEN-TF-8  
BRY-DS-407  
SBK-DS-107  
OHB-CB-1102  
HWA-DS-87  
CST-CB-7  
CST-VT-38  
OTA-DS-565  
UHT HEI  
NMA-TF-ET1  
CPK-TF-5  
PAP-REA-3  
CST-NPL2 HEI  
GYM HEI  
HAY-WIL1 HEI  
MTN-DS-1087  
OTA-DS-506  
NPK Cust\_Fault  
OKI C&I  
KIN-TRK1  
TWZ HEI  
COL-OTI2 HEI  
CLH-COL1 HEI  
EDN-TF-1  
HEN-CB-282  
ADD-CB-122  
ADD Prot  
TKR-WIL1 HEI  
BRY-CT-82  
ADD-CB-28  
HEP-TF-1  
STK 33kV Bus  
STK Stn\_Serv  
STK-CB-432  
OAM-BPT-WTK1  
IGH-KIK1  
KIK Prot  
DOB-RFN-IGH1  
MDN Prot  
TKR-CB-112  
DVK-WDV1

IGH-ROB-WPT1  
FKN 33kV Bus  
ISL-DS-355  
SPN HEI  
HEN-TF-ET3  
CST-TF-2  
OAM-STU-WTK2 HEI  
PEN-TF-9  
WPT-TF-2  
ALB-HPI1  
ALB-HEN3  
IGH-RFN2  
PRM Cust\_Fault  
OTA-ROS1  
MPE HEI  
STU HEI  
PAP-TF-1  
KIK-DS-366  
WGN Stn\_Serv  
KUM Prot  
DOB Sys\_Conditions  
OAM-VT-3  
WDV-TF-1  
BRK-CVT-2  
OKI Prot  
ABY C&I  
BEN-OHB1  
CYD-TF-8  
FHL-CB-312  
PAK-PEN1  
DVK-TF-1  
NPL-CB-72  
CLH C&I  
MDN Gen\_Fault  
OKN-CB-72  
LTN-CB-152  
BOB-DS-44  
STU-CB-72  
MDN C&I  
HEP-TF-2  
SFD Sys\_Conditions  
BRK Sys\_Conditions  
GLN-DS-1455  
ISL-KIK2  
WKO-CB-552  
GLN-DS-1664  
HAM-REA-2  
WRK-DS-146  
BEN-DS-493  
BPE-CT-532  
TRK-DS-237  
TMK-CB-1232

CST Cust\_Fault  
KOE Sys\_Conditions  
OTA-CB-10  
KIK-DS-106  
TKH-CB-1  
MTM-CB-92  
OAM Cust\_Fault  
WPT Unknown  
BPE-MHO2 HEI  
ROS-TF-3  
ADD-TF-5  
COB-UTK1 Comms  
WDV Reg  
IGH-ROB-WPT2  
MPI-UTK1  
CST-NPL2  
CST-NPL1  
OWH Prot  
HWB HEI  
TIM-TF-5  
ISL-TF-1  
TKH Prot  
MTM-TF-3  
RDF Cust\_Fault  
SVL-TF-1  
OTA-DS-974  
HEN-SWN1  
GLN-TAK-OTA1  
INV-ROX1  
KIN-TRK2  
WGN-DS-96  
IGH-KIK-MCH1  
BLN-STK2  
MTM Unknown  
CLH-COL1  
MST-CB-72  
COL-HOR3 HEI  
HOR-DS-106  
NPL-VT-39  
HIN-CB-232  
HEN-OTA1  
ISL-CB-4112  
PEN-DS-744  
PEN-DS-756  
WPR C&I  
KPU-TF-4  
WPT Surge\_Arr  
HLY-OTA1  
OTA-DS-585  
OTA-DS-583  
TMU HEI  
OTA-CB-39

ASY-TF-3  
TMK-CB-112  
ONG Cust\_Fault  
WVY-DS-94  
TKA HEI  
WDV-CB-11  
ASB-VT-3  
COB Scada  
OTA-DS-563  
WTU Comms  
APS-OTI1  
ATU-RFN-IGH1  
WIL-DS-133  
BDE-CB-17  
BDE-CB-21  
ASY-SBK1  
HAM-KPO1  
TIM-TF-8  
WTU C&I  
HEN-HEP4  
OKN Prot  
OTA Cust\_Fault  
BOB-CB-142  
MDN 110kV Bus  
MDN-VT-52  
MDN-TF-2  
TRK 11kV Bus  
BRK-SFD3  
WRK-DS-144  
MDN 220kV Bus  
TIM-TF-3  
WGN-CB-2052  
MPE-TF-4  
KIK-DS-84  
KIK-DS-104  
OTA-CB-972  
OTA-CB-562  
ISL-CB-1422  
OTA-CB-422  
OWH-DS-104  
OWH-CB-92  
ONG-DS-174  
TMI Cust\_Fault  
ABY-TIM1  
ISL-CB-152  
TNG Prot  
RDF-TUI2 HEI  
ISL-TF-3  
ALB-CB-902  
TWH-DS-456  
EDG-OWH2  
BPE-TF-15

KIN-CB-2242  
RDF Prot  
ATI-TRK2  
ONG Prot  
ISL Stn\_Serv  
HEN-WEL-MTO-MPE1  
CLH-DS-644  
COL-CLH-APS-OTI1  
WPT Reg  
ARI-DS-156  
ARI-DS-146  
KIK Unknown  
KAW-CT-FDRA  
OHA Prot  
BOB-TF-3  
COL-HOR2 Sys\_Conditi  
TWH Prot  
HWA Prot  
SPN 33kV Bus  
ADD-CB-102  
TUI-TF-15  
WHU-TF-3  
HKK Cust\_Fault  
HEN-WEL-MTO-MPE2  
FHL Scada  
BRB-VT-13  
FKN-TF-4  
TMI Unknown  
NMA-TF-1  
LTN Prot  
ATU Prot  
GYT-TF-3  
MTI 220kV Bus  
OTA-CB-162  
TMU-DS-84  
BRK-SFD1 HEI  
HAY-CB-82  
HEN-REA-5A  
GLN-DS-605  
BRY-CB-92  
GYT HEI  
TUI-DS-134  
DAR Prot  
OKI-DS-275  
TKR HEI  
KMO-TMI1  
HEN-CB-312  
STU-TIM1 HEI  
BRY Scada  
BRY-TF-2  
BAL-BWK-HWB1  
HEN-TF-1

ROS-DS-114  
HOR HEI  
ALB-DS-727  
TKA-ABY-TIM1  
PEN Cust\_Fault  
TKH 11kV Bus  
HUI Prot  
OTA-PEN6  
MLG-DS-54  
WHU-CB-92  
OKI-CB-1012  
KAW-CB-172  
TWZ-CB-2412  
KWA-TF-2  
BAL C&I  
ROS-CB-112  
BAL-TF-1  
MPE-VT-34  
TUI-CB-24  
CBG Prot  
ALB-SVC-7  
GOR Surge\_Arr  
STK-CB-2182  
BOB-WIR-OTA2  
WRA-TF-2  
ATU-DOB1  
EDG-OWH2 HEI  
BOB Prot  
KAI-TF-2  
ALB-CAP-2  
OTA-CB-502  
HEN-WEL1  
TGA-DS-1204  
KTA Scada  
WRA-CB-37  
KIK HEI  
HAY-MLG1  
WDV-DS-44  
GYT Prot  
HAY-CB-112  
WDV Sys\_Conditions  
MST Sys\_Conditions  
BEN HEI  
OKI-VT-40  
ARI-KIN1 HEI  
OTA 220kV Bus  
OKI-DS-306  
ALB-TF-4  
PNI C&I  
SDN 220kV Bus  
MHO-PRM1 HEI  
MPE-CB-242

HLY C&I  
TKU-DS-86  
CPK-WIL2  
HWA-CB-102  
ADD Cable\_Conn  
PAK-DS-636  
ONG-DS-214  
TMU 110kV Bus  
KAW-TF-ET6  
GLN-TAK-OTA1 HEI  
MDN Cust\_Fault  
FHL-RDF2 HEI  
KIN-LFD-TRK1 HEI  
DVK-DS-104  
ISL Sys\_Conditions  
ISL-DS-805  
RDF-TF-LS1  
TGA-DS-274  
ROT Cable\_Conn  
TKA-CB-37  
HAY-CB-272  
ASB-TIM-TWZ2  
PAL-TF-1  
HWB-TF-2  
WDV Cable\_Conn  
HEN-CB-272  
COL Scada  
SFD-CB-72  
OKI-CB-302  
OHC-CB-1358  
OWH-TMI-TRK1 HEI  
HUI-TF-6  
MDN-TF-3  
BRY-REA-4  
MPE-CB-222  
WHU HEI  
ARI-CB-202  
EDG-TF-4  
KMO-MTM-TGA2  
KMO Prot  
FHL-RDF1  
OWH Scada  
KIN HEI  
PAP-REA-2  
BRY-TF-3  
WWD Prot  
CYD MetalClad\_Conn  
NMA-CVT-8  
TMI HEI  
GYM-DS-104  
TWH Comms  
BPE-CT-552

KOE-CB-1202  
BPE-DS-895  
WWD HEI  
CYD Gen\_Fault  
WWD-CB-242  
MNI-TF-3  
ISL-TF-7  
OTA-CB-2832  
MOT Cable\_Conn  
MOT Sys\_Conditions  
OTI Sys\_Conditions  
BAL Cable\_Conn  
ISL-WPR-CUL-KIK2  
SVL-TF-2  
CPK-WWD-WIL3  
CPK-WWD-WIL2  
MHO-CB-302  
TWZ-CB-2562  
CST Prot  
EDG-WAI2 HEI  
WRK-DS-103  
IGH-CVT-362  
ISL-TF-LS1  
ISL-CAP-15  
OHC Prot  
HEN-OTA1 HEI  
CYD-CVT-442  
MPE-DS-244  
MLG-TF-1  
CST-CB-62  
GFD HEI  
BEN-TF-29  
CPK C&I  
APS-TF-1  
KAW-OHK1 HEI  
OTA Scada  
CPK Cust\_Fault  
ISL-CAP-16  
GOR-CB-72  
KTA-CB-1092  
WEL HEI  
CST HEI  
ROS-DS-106  
PAK-DS-594  
TIM 110kV Bus  
WHI-TF-1  
HAY-WIL1  
PAP-DS-114  
OTA-CB-172  
MTM-DS-44  
MLG-VT-39  
STK Sys\_Conditions

BDE Prot  
EDG-DS-207  
HWB-ROX2 HEI  
HWB-ROX1 HEI  
HAM-OHW1  
KAW-DS-176  
TKR Stn\_Serv  
BPE-CT-692  
OTA-TF-4  
STK Cust\_Fault  
TAK-CB-1362  
HEP-CB-1182  
HWB C&I  
BDE-CB-18  
TIM Cust\_Fault  
BDE Scada  
MGM-MST1 HEI  
TWZ C&I  
TMI Prot  
BRB Cust\_Fault  
EDN Prot  
BEN-TF-27  
TWH Sys\_Conditions  
OWH Cable\_Conn  
NSY HEI  
ISL-DS-479  
OTI Cust\_Fault  
OHW-WKM1  
HAM-WKM1  
OKI-WRK1  
TRK-TF-2  
TMU 11kV Bus  
OTA-ROS2  
OTA 11kV Bus  
ISL-WPR-CUL-KIK3  
CST-CB-142  
OHB Gen\_Fault  
EDG-KAW2 HEI  
STU Sys\_Conditions  
GYM-KUM1 HEI  
KOE-KTA1 HEI  
ISL-SVC-9  
SDN-DS-477  
DOB-CB-132  
GYM Cust\_Fault  
DOB C&I  
GOR HEI  
PAP-REA-4  
WHI Prot  
KAW-CB-26  
FKN HEI  
OPK Cust\_Fault

BEN C&I  
SDN-DS-1034  
OTA-CT-302  
BRY Cable\_Conn  
KIK-SVC-2B  
WDV-DS-46  
OKI-DS-305  
HAY-CB-182  
KIK C&I  
WTK Stn\_Serv  
WTU-DS-814  
HAM C&I  
ROS-DS-1064  
MDN Sys\_Conditions  
GYM C&I  
TMH HEI  
ATI-WKM1  
KTA-CAP-1  
MTM-CT-52  
BRB-CB-122  
TNG-TF-12  
HKK Prot  
TMN Comms  
EDN-DS-46  
TWC Gen\_Fault  
ALB-CB-222  
HWA-DS-324  
LTN HEI  
TGA-CB-39  
SPN-DS-1224  
OKI-DS-276  
SPN-TF-2  
SPN-TF-1  
ISL-TF-6  
ISL-PAP4  
ADD-MLN-ISL1  
SPN Scada  
ADD-DS-256  
ISL Surge\_Arr  
TKH C&I  
SDN-TMH1  
ATU Comms  
TUI-CB-122  
GLN-DS-1494  
TUI Prot  
BEN-VT-1139  
KIN Sys\_Conditions  
HIN-DS-227  
KIK Stn\_Serv  
ONG-DS-64  
BOB-HAM2  
WHI-TF-2

OTA-DS-576  
OHA Gen\_Fault  
UTK Prot  
STK-CB-212  
UTK-CB-192  
SDN 33kV Bus  
ADD-DS-136  
ISL-DS-546  
DAR-CB-72  
KIK-SVC-2A  
HPI-MDN1  
PRM Cable\_Conn  
PRM 33kV Bus  
OAM-TF-1  
OPK C&I  
MTO Comms  
ROT C&I  
BLN-CB-102  
TMI 110kV Bus  
TMI-CB-102  
HTI Cust\_Fault  
CUL-TF-ET1  
MAT HEI  
ALB-TF-7  
NPK HEI  
BRY-TF-6  
BRY-TF-5  
ADD-TF-7  
UTK-CB-202  
BRY-DS-804  
BRY-CB-39  
OTA-DS-423  
OTA-TF-ET4  
OKI-WRK3 HEI  
WIR C&I  
OPK-SFD1 HEI  
TKH HEI  
MAT Stn\_Serv  
WPW Cable\_Conn  
ADD Surge\_Arr  
WRK-TF-30  
HOR-ISL1 HEI  
OTA-DS-575  
TMI Cable\_Conn  
CBG-CB-242  
EDG-DS-424  
WKO-CB-292  
ABY-CB-62  
DRY-HLY1  
KTA-CB-Q3  
PAP-TF-4  
BRY-TF-ET5

WIL Prot  
EDG-CB-272  
WEL-CB-1042  
TNG-DS-225  
OTA-TF-11  
TAK-TF-5  
KIN-CB-352  
HAY-UHT1  
OWH-VT-4  
KMO-TRK2  
KMO-TRK1  
KPO-CB-92  
HAY-LTN1  
BPE-TWC-LTN1  
HEN-CT-522  
HAM 110kV Bus  
CST-HUI1  
HEN-CB-322  
TMI MetalClad\_Conn  
BPE-CB-632  
HAM-TF-4  
WPW-CB-52  
GOR-TF-3  
INV Cable\_Conn  
ROT-TRK2  
HAM-TF-6  
GIS Sys\_Conditions  
HAY-CB-822  
ROX-TF-10  
MTM-PIE2 HEI  
WIL-CB-192  
ROS-DS-126  
PRM-PNI-TKR2 HEI  
PRM-PNI-TKR1 HEI  
TWH-TF-1  
ONG-DS-154  
HTI-DS-107  
HLY-TF-ET22  
PAK-DS-656  
RPO-CB-632  
DOB-RFN-IGH2  
TKB Sys\_Conditions  
OTA-CB-1422  
HAY-CB-132  
MHO-DS-314  
FHL HEI  
GLN-DS-1674  
WVY Cust\_Fault  
ISL-LIV1 HEI  
WTU Prot  
ALB-CB-702  
TKU HEI

```
TRK HEI
ISL-VT-2112
GIS HEI
WPT-VT-39
WTU-CB-1102
BWK-CB-82
STU-DS-77
BAL-GOR1 HEI
EDN HEI
HIN Prot
HEN-CB-292
MTM-PIE2
OTA-TF-12
WVY-DS-46
MNI Prot
MOT HEI
WPW-CB-232
KEN-TF-2
WPT-CT-39
WTK Surge_Arr
BDE-CB-122
WAI-TF-2
MNG Comms
WHU-CB-282
CBG-CB-39
ADD-TF-3
ROT-DS-366
KIK Cust_Fault
CLH-TF-1
APS-CLH1
ALB-TF-6
ASB-VT-1
KAW-VT-26
DRY Prot
MTR-OKN1
```

```
events = hvac.groupby(hvac.Ident)

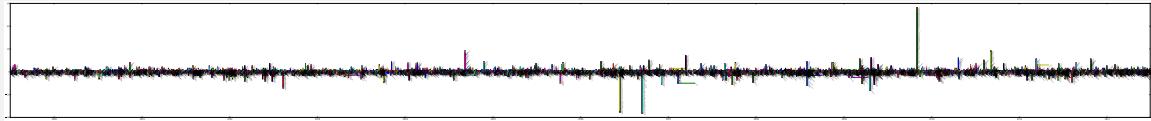
#Plot an 'outage tree'
#Ok this bit of code attempts to plot the forced outages over time

plt.figure(1,figsize=[100,10])
flipper = -1.0
for event,data in events: #cycle through the events
    flipper = flipper*(-1.0)
    datas = data.sort(columns='Start',ascending=False)
    y = range(datas.Flt_Item.count())
    xs = datas.Start.tolist()
    xe = datas.End.tolist()
    outage_id = datas.Rem_Item.tolist()
    x=0
```

```

for XSS in xs:
    #print [xs[x],xe[x]], [y[x],y[x]]
    plt.plot([xs[-1],xs[-1]],[0,flipper*datas.Flt_Item.count()])
    hold('on')
    plot([xs[x],xe[x]],[((flipper*y[x]+flipper),(flipper*y[x]+flipper))])
    plt.annotate(outage_id[x],xy = (xe[x], (flipper*y[x]+flipper)),rotation=flipper
                *45,fontsize=4)
    x+=1

```



```

def outage_tree(ydata,year):
    #Plot an 'outage tree'
    #Ok this bit of code attempts to plot the forced outages over time
    print ydata
    events = ydata.groupby(ydata.Ident)
    #plt.figure(figsize=[20,20])
    flipper = -1.0
    for event,data in events: #cycle through the events
        flipper = flipper*(-1.0)
        datas = data.sort(columns='Start',ascending=False)
        y = range(datas.Flt_Item.count())
        xs = datas.Start.tolist()
        xe = datas.End.tolist()
        outage_id = datas.Rem_Item.tolist()
        x=0
        for XSS in xs:
            #print [xs[x],xe[x]], [y[x],y[x]]
            plot([xs[-1],xs[-1]],[0,flipper*datas.Flt_Item.count()])
            hold('on')
            plot([xs[x],xe[x]],[((flipper*y[x]+flipper),(flipper*y[x]+flipper))])
            #annotate(outage_id[x],xy = (xe[x], (flipper*y[x]+flipper)),rotation=flipper*45)
            x+=1
    #title(year)
    #xlabel('Date and time')
    #ylabel('Number of removed items')
    xlim([datetime(year,1,1,0,0),datetime(year+1,1,1,0,0)])
    ylim([-10,10])

```

```
hvac2 = hvac.set_index(['Ident','Flt_Item'])
```

```
hvac3 = hvac2.groupby(level=1)
```

```
hvac2
```

```

<class 'pandas.core.frame.DataFrame'>
MultiIndex: 9168 entries, (u'SS99101', u'LIV-NSY1') to (u'SN11379', u'HEN-WEL-MTO-MPE1')
Data columns:
Date          9168 non-null values
Rem_Item      9168 non-null values
Start         9168 non-null values
End           9168 non-null values
Delta          9168 non-null values
TX             482 non-null values
dtypes: object(6)

```

```

plt.figure(figsize=[20,40])
hvac_year = hvac.groupby(hvac.Start.map(lambda x: x.year))
i=0
for year,yearly_data in hvac_year:
    subplot(12,1,i)
    print year,len(yearly_data.index)
    outage_tree(yearly_data,year)
    i+=1
plt.title('HVAC: Enduring Forced Asset Outage tree')
plt.savefig('test.png', bbox_inches='tight')

```

```

1999 260
<class 'pandas.core.frame.DataFrame'>
Int64Index: 260 entries, 0 to 259
Data columns:
Ident         260 non-null values
Flt_Item      260 non-null values
Date          260 non-null values
Rem_Item      260 non-null values
Start         260 non-null values
End           260 non-null values
Delta          260 non-null values
TX             9 non-null values
dtypes: object(8)
2000
625
<class 'pandas.core.frame.DataFrame'>
Int64Index: 625 entries, 260 to 884
Data columns:
Ident         625 non-null values
Flt_Item      625 non-null values
Date          625 non-null values
Rem_Item      625 non-null values
Start         625 non-null values
End           625 non-null values
Delta          625 non-null values
TX             53 non-null values
dtypes: object(8)
2001

```

```
735
<class 'pandas.core.frame.DataFrame'>
Int64Index: 735 entries, 885 to 1619
Data columns:
Ident      735 non-null values
Flt_Item   735 non-null values
Date       735 non-null values
Rem_Item   735 non-null values
Start      735 non-null values
End        735 non-null values
Delta      735 non-null values
TX         57  non-null values
dtypes: object(8)
2002

738
<class 'pandas.core.frame.DataFrame'>
Int64Index: 738 entries, 1620 to 2357
Data columns:
Ident      738 non-null values
Flt_Item   738 non-null values
Date       738 non-null values
Rem_Item   738 non-null values
Start      738 non-null values
End        738 non-null values
Delta      738 non-null values
TX         38  non-null values
dtypes: object(8)
2003

554
<class 'pandas.core.frame.DataFrame'>
Int64Index: 554 entries, 2358 to 2911
Data columns:
Ident      554 non-null values
Flt_Item   554 non-null values
Date       554 non-null values
Rem_Item   554 non-null values
Start      554 non-null values
End        554 non-null values
Delta      554 non-null values
TX         20  non-null values
dtypes: object(8)
2004

662
<class 'pandas.core.frame.DataFrame'>
Int64Index: 662 entries, 2912 to 3573
Data columns:
Ident      662 non-null values
Flt_Item   662 non-null values
Date       662 non-null values
Rem_Item   662 non-null values
```

```
Start      662 non-null values
End        662 non-null values
Delta      662 non-null values
TX         41 non-null values
dtypes: object(8)
2005

649
<class 'pandas.core.frame.DataFrame'>
Int64Index: 649 entries, 3574 to 4222
Data columns:
Ident      649 non-null values
Flt_Item   649 non-null values
Date       649 non-null values
Rem_Item   649 non-null values
Start      649 non-null values
End        649 non-null values
Delta      649 non-null values
TX         30 non-null values
dtypes: object(8)
2006

1011
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1011 entries, 4223 to 5233
Data columns:
Ident      1011 non-null values
Flt_Item   1011 non-null values
Date       1011 non-null values
Rem_Item   1011 non-null values
Start      1011 non-null values
End        1011 non-null values
Delta      1011 non-null values
TX         41 non-null values
dtypes: object(8)
2007

674
<class 'pandas.core.frame.DataFrame'>
Int64Index: 674 entries, 5234 to 5907
Data columns:
Ident      674 non-null values
Flt_Item   674 non-null values
Date       674 non-null values
Rem_Item   674 non-null values
Start      674 non-null values
End        674 non-null values
Delta      674 non-null values
TX         31 non-null values
dtypes: object(8)
2008

786
<class 'pandas.core.frame.DataFrame'>
```

```
Int64Index: 786 entries, 5908 to 6693
Data columns:
Ident      786 non-null values
Flt_Item   786 non-null values
Date       786 non-null values
Rem_Item   786 non-null values
Start      786 non-null values
End        786 non-null values
Delta      786 non-null values
TX         39  non-null values
dtypes: object(8)
2009

877
<class 'pandas.core.frame.DataFrame'>
Int64Index: 877 entries, 6694 to 7570
Data columns:
Ident      877 non-null values
Flt_Item   877 non-null values
Date       877 non-null values
Rem_Item   877 non-null values
Start      877 non-null values
End        877 non-null values
Delta      877 non-null values
TX         40  non-null values
dtypes: object(8)
2010

750
<class 'pandas.core.frame.DataFrame'>
Int64Index: 750 entries, 7571 to 8320
Data columns:
Ident      750 non-null values
Flt_Item   750 non-null values
Date       750 non-null values
Rem_Item   750 non-null values
Start      750 non-null values
End        750 non-null values
Delta      750 non-null values
TX         29  non-null values
dtypes: object(8)
2011

847
<class 'pandas.core.frame.DataFrame'>
Int64Index: 847 entries, 8321 to 9167
Data columns:
Ident      847 non-null values
Flt_Item   847 non-null values
Date       847 non-null values
Rem_Item   847 non-null values
Start      847 non-null values
End        847 non-null values
```

```

Delta      847 non-null values
TX         54 non-null values
dtypes: object(8)

```

```

hvac_year = hvac.groupby(hvac.Start.map(lambda x: x.year))
total_events={}
size_events = {}
for year,yearly_data in hvac_year:
    x={}
    xs={}
    ident_data = yearly_data.groupby(yearly_data.Ident)
    for ident,ident_data in ident_data:
        x[ident_data.Start.tolist()[0]]=ident_data.Start.tolist()[0]
        xs[ident_data.Start.tolist()[0]]=len(ident_data.Start.tolist())
    x=Series(x)
    xs=Series(xs)
    print 'No events = ' + str(len(x.diff().tolist()[1:])-1) + ': Mean time between
          events for ' + str(year) + ' : ' + str(sum(x.diff().tolist()[1:])/len(x.diff().
          tolist()[1:])-1))
    total_events[year]=len(x.tolist())
total_events = Series(total_events)

```

```

No events = 176: Mean time between events for 1999 : 1 day, 0:14:23.181818
No events = 419: Mean time between events for 2000 : 20:55:41.384248
No events = 519: Mean time between events for 2001 : 16:44:00
No events = 486: Mean time between events for 2002 : 17:56:34.814814
No events = 379: Mean time between events for 2003 : 22:56:45.277044
No events = 423: Mean time between events for 2004 : 20:44:42.836879
No events = 439: Mean time between events for 2005 : 19:48:06.697038
No events = 584: Mean time between events for 2006 : 14:55:15.205479
No events = 422: Mean time between events for 2007 : 20:41:53.317535
No events = 520: Mean time between events for 2008 : 16:51:18.115384
No events = 498: Mean time between events for 2009 : 17:34:01.686746
No events = 448: Mean time between events for 2010 : 19:26:10.580357
No events = 493: Mean time between events for 2011 : 17:33:52.332657

```

```

x={}
#total outages per year
for year,yeardata in byyear:
    print year,len(yeardata.Flt_Item)
    x[year] = len(yeardata.Flt_Item)
total_outages=Series(x)
total_outages[1:].plot(kind='bar',title='Total recorded forced outages per year (all
types)')

```

```
event_outages = DataFrame({'events':total_events[1:], 'outages':total_outages[1:]})
```

```
1999 260
2000 625
2001 735
2002 738
2003 554
2004 662
2005 649
2006 1011
2007 674
2008 786
2009 877
2010 750
2011 847
```

```
plt.figure(1, figsize=[20,20]);
event_outages.plot(kind='bar', figsize=[20,20])
```

```
<matplotlib.axes.AxesSubplot at 0x559ec50>
```

Ok, fit a straight line (using a simple ordinary least squares model) and output some statistics on annual events

```
import statsmodels.api as sm
```

```
X = np.array(event_outages.outages.index.tolist())
X = sm.add_constant(X)
results_outages = sm.OLS(event_outages.outages, X).fit()
results_events = sm.OLS(event_outages.events, X).fit()
```

```
/usr/local/lib/python2.7/dist-packages/statsmodels-0.5.0-py2.7-linux-x86_64.egg/statsmodels/tools/tools.
FutureWarning)
```

```
X
```

```
array([[ 1.,  1.],
       [ 2.,  1.],
       [ 3.,  1.],
       [ 4.,  1.],
       [ 5.,  1.],
       [ 6.,  1.],
       [ 7.,  1.]])
```

```
event_outages.outages.plot()
(results_outages.fittedvalues).plot(style='r')
event_outages.events.plot()
(results_events.fittedvalues).plot(style='r')
```

```
<matplotlib.axes.AxesSubplot at 0x77c99d0>
```

```
results_events.summary()
```

```
/usr/lib/python2.7/dist-packages/scipy/stats/stats.py:1198: UserWarning: kurtosistest only valid for n>
int(n)

<class 'statsmodels.iolib.summary.Summary'>
"""
                OLS Regression Results
=====
Dep. Variable:           events    R-squared:         0.059
Model:                 OLS      Adj. R-squared:   -0.035
Method:                Least Squares   F-statistic:      0.6260
Date:          Wed, 03 Oct 2012   Prob (F-statistic): 0.447
Time:            11:29:25       Log-Likelihood:   -64.751
No. Observations:      12        AIC:             133.5
Df Residuals:          10        BIC:             134.5
Df Model:               1
=====
            coef    std err        t      P>|t|      [95.0% Conf. Int.]
-----
x1          3.8671     4.887     0.791      0.447      -7.023    14.757
const      -7284.3683  9801.866    -0.743      0.474     -2.91e+04  1.46e+04
=====
Omnibus:                 1.075   Durbin-Watson:      2.524
Prob(Omnibus):            0.584   Jarque-Bera (JB):  0.734
Skew:                      0.551   Prob(JB):        0.693
Kurtosis:                  2.496   Cond. No.      1.17e+06
=====
```

The condition number is large, 1.17e+06. This might indicate that there are strong multicollinearity or other numerical problems.

```
"""
```

```
results_outages.summary()
```

```
<class 'statsmodels.iolib.summary.Summary'>
"""
                OLS Regression Results
=====
Dep. Variable:           outages    R-squared:         0.265
Model:                 OLS      Adj. R-squared:   0.191
Method:                Least Squares   F-statistic:      3.598
Date:          Wed, 03 Oct 2012   Prob (F-statistic): 0.0871
Time:            11:29:41       Log-Likelihood:   -72.618
No. Observations:      12        AIC:             149.2
Df Residuals:          10        BIC:             150.2
Df Model:               1
=====
            coef    std err        t      P>|t|      [95.0% Conf. Int.]
```

```

x1          17.8601    9.415     1.897     0.087     -3.118    38.839
const      -3.508e+04  1.89e+04   -1.858     0.093     -7.71e+04  6996.361
=====
Omnibus:                  5.945  Durbin-Watson:           2.716
Prob(Omnibus):            0.051  Jarque-Bera (JB):       2.550
Skew:                      1.037  Prob(JB):              0.279
Kurtosis:                 3.893  Cond. No.           1.17e+06
=====
```

The condition number is large, 1.17e+06. This might indicate that there are strong multicollinearity or other numerical problems.

"""

```
\sum_i
```

```

Y = [1,3,4,5,2,3,4]
X = range(1,8)
X = sm.add_constant(X)
model = sm.OLS(Y,X)
results = model.fit()
```

```

plot(X[:,0],Y)
plot(X[:,0],results.fittedvalues,'r')
```

[<matplotlib.lines.Line2D at 0x6f6c5d0>]

```
(event_outages['outages']/event_outages['events'].map(lambda x: float(x))).plot(kind='bar')
```

<matplotlib.axes.AxesSubplot at 0x77c99d0>

```
X[:,0]
```

array([ 1., 2., 3., 4., 5., 6., 7.])

```
a=sum(x.diff().tolist()[1:])/len(xx)-1
```

```
print a
```

17:31:44.331983

```
sum(x.diff().tolist(), timedelta()) / len(x.diff())
```

```
-----
TypeError                                Traceback (most recent call last)
<ipython-input-152-bacfac4eadc2> in <module>()
----> 1 sum(x.diff().tolist(), timedelta()) / len(x.diff())

/usr/lib/python2.7/dist-packages/numpy/core/fromnumeric.pyc in sum(a, axis, dtype, out)
    1452         sum = a.sum
    1453     except AttributeError:
-> 1454         return _wrapit(a, 'sum', axis, dtype, out)
    1455     return sum(axis, dtype, out)
    1456

/usr/lib/python2.7/dist-packages/numpy/core/fromnumeric.pyc in _wrapit(obj, method, *args, **kwds)
    35     except AttributeError:
    36         wrap = None
-> 37     result = getattr(asarray(obj),method)(*args, **kwds)
    38     if wrap:
    39         if not isinstance(result, mu.ndarray):

TypeError: an integer is required
```