Calculating How Much Solar Power Can Be Injected Into The Grid

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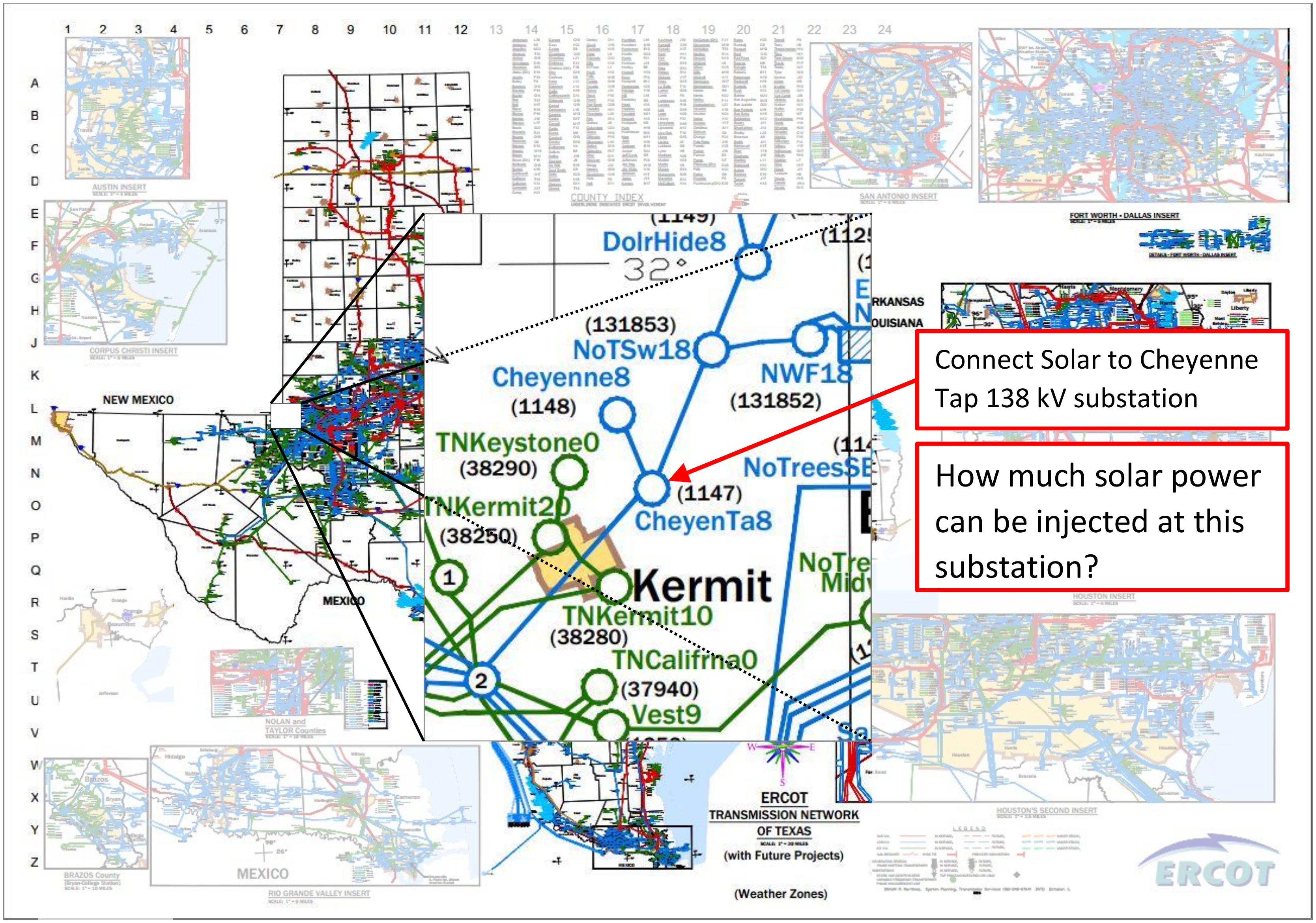
We will use a specific location in ERCOT as an example:



We need these items to perform a study:

1. The county or physical location of the solar plant. ✓
2. A map showing nearby power lines and substations. ✓
3. The target year (2018) the facility will go into service. ✓
4. An ERCOT 2018 summer peak power flow base case. ✓
5. Any other nearby planned solar plants or wind farms. ✓
6. Where the power is sent to (if its a bilateral contract). ✓
7. An electrical model to perform the ATC* calculations. ✓

* ATC is the available transfer capability or capacity. As more power is sent from the POI (point of interconnection) to other areas, lines load up. Most ATC MW limits happen for lines loading to 100% of their thermal capacities.

We need to test voltage sensitivity to injected reactive power. An AC load flow can indicate the effect of reactive power:

- Test minimal voltage control – Inject MW power with 0 Mvar (unity power factor) and if the POI voltage changes little under all line outage tests, then the POI will have good voltage control.

- If not, then turn on the normal reactive voltage control, which is +/- 95% power factor or a reactive power range about +/-1/3rd of the real maximum power (Pmax). Voltages should be fine.

- Poor voltage regulation is when voltages sag or rise even with 95% power factor, and you probably should avoid this substation POI.

Steps needed to find the ATCs (limiting lines and MWs):

1. Run two base cases, POI = 0 MW, and POI = 100 (or more) MW.
2. Identify lines with ½% delta MW/POI as study area lines (~1000).
3. Run zipflow analysis (fast AC load flow*) study area - both cases.
4. Identify overloaded lines and sort the zipflow ATCs, lowest first.
5. Run full AC load flows for zipflow results for only real MW POI.
6. Compare zipflow ATCs and AC load flow ATCs and if ok, stop.
7. If AC results are quite different, turn on POI reactive +/-95% PF.
8. If 7 as a normal condition is ok, then stop.
9. If 7 is not ok, check voltages, and if not ok, then list as a poor site.

* see zipflow pages 123-128 http://egpreston.com/bookmod.pdf

ATC results for adding solar NE of Kermit Texas

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Available Transfer Capability Summary:
New generation added to the base case =    150 MW  ---------------.
Number of lines outaged and monitored =   1023                    V
                                                           ratg  %-of-ratg   dist    ATC
        -------from-------   --------to-------- ID mi   MVA  0-MW X-MW   fact     MW
outage:  6655 BARL4A   138 - 60385 SOLSTICE 138 1
 loads: 60385 SOLSTICE 138 - 60393 PIGCREEK 138 1  13   151   103   98  0.048    83 min
           71 mi  from          1147 CHEYENTA 138                   AC load flow  95 min
```

Min is the opposite of a constraint. The solar POI unloads a slightly overloaded line.

```
outage:  1149 DOLRHIDE 138  131853 NOTSW_1_ 138 1
 loads:  1074 WINKSS_8 138 -  1147 CHEYENTA 138 1  13   171     4   89  0.947   174 max   1st
            0 mi  from          1147 CHEYENTA 138                   AC load flow 173 max
```

The ATC is 173 MW. Minimum solar plant reactive is needed to control the voltage.

```
outage:  1074 WINKSS_8 138 -  1147 CHEYENTA 138 1
 loads:  1149 DOLRHIDE 138  131853 NOTSW_1_ 138 1  14   171     4   89  0.946   174 max   2nd
           14 mi  from          1147 CHEYENTA 138                   AC load flow 175 max

outage:  1074 WINKSS_8 138 -  1147 CHEYENTA 138 1
 loads:  1149 DOLRHIDE 138 -  1150 AMOCO3BA 138 1   6   171     9   81  0.947   189 max
           27 mi  from          1147 CHEYENTA 138                   AC load flow 192 max

outage:  1074 WINKSS_8 138 -  1147 CHEYENTA 138 1
 loads:  1150 AMOCO3BA 138 -  1157 ANDRCOSO 138 1   5   171    10   79  0.948   193 max
           33 mi  from          1147 CHEYENTA 138                   AC load flow 196 max

outage:  1074 WINKSS_8 138 -  1147 CHEYENTA 138 1
 loads:  1147 CHEYENTA 138  131853 NOTSW_1_ 138 1  14   171     7   79  0.947   194 max
            0 mi  from          1147 CHEYENTA 138                   AC load flow 196 max
```

Other Nearby Generators Affecting the ATCs on the 1st Limiting Line

RUN 3 ovlds: 1074 WINKSS_8 138 - 1147 CHEYENTA 138 1

+PDFs are harmers		-PDFs are helpers		PMAX	BGEN	DIFF
GEN	**1147**	**CHEYENTA 138 S**	**PDF= 0.5509**	**-**	**-**	**-**
GEN	131851	NWF_NWF134.5 W	PDF= 0.2846	152.60	18.28	134.32
GEN	130011	PB2SES_C13.8	PDF= -0.1090	68.00	67.88	0.12
GEN	130012	PB2SES_C13.8	PDF= -0.1090	65.00	64.88	0.12
GEN	130013	PB2SES_C13.8	PDF= -0.1090	68.00	67.88	0.12
GEN	130014	PB2SES_C13.8	PDF= -0.1090	69.00	68.88	0.12
GEN	130015	PB2SES_C13.8	PDF= -0.1090	70.00	69.87	0.13
GEN	132332	REROCK_U34.5 S	PDF= -0.0752	78.75	62.89	15.86
GEN	132333	REROCK_U34.5 S	PDF= -0.0752	78.75	62.89	15.86
GEN	181651	HOVEY_UN34.5 S	PDF= -0.0752	29.40	23.48	5.92
GEN	170200	ACA_UNIT34.5 S	PDF= -0.0729	9.99	7.98	2.01
GEN	132481	RIGGINS_34.5 S	PDF= -0.0411	150.00	119.78	30.22
GEN	132311	ECEC_G1 18	PDF= 0.0299	147.01	146.74	0.27
GEN	132312	ECEC_G2 18	PDF= 0.0299	147.01	146.74	0.27
GEN	130431	WOO_WOOD34.5 W	PDF= -0.0138	82.50	9.88	72.62
GEN	130531	WOO_WOOD34.5 W	PDF= -0.0134	77.22	9.25	67.97
GEN	131451	KEO_KEO_34.5 W	PDF= -0.0121	150.00	17.97	132.03
GEN	131455	KEO_SHRB34.5 W	PDF= -0.0120	147.50	17.67	129.83
GEN	132431	SIRIUS_U34.5 S	PDF= -0.0111	110.20	88.00	22.20
GEN	132436	SIRIUS_U34.5 S	PDF= -0.0110	50.00	39.93	10.07
GEN	130331	INDN_IND34.5 W	PDF= -0.0106	82.50	9.88	72.62
GEN	131031	INDN_IND34.5 W	PDF= -0.0100	84.00	10.06	73.94

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mostly negatives (helpers)

Other Nearby Generators Affecting the ATCs on the 2nd Limiting Line

```
RUN    4  ovlds:  1149 DOLRHIDE 138 -131853 NOTSW_1_ 138 1
+PDFs are harmers  -PDFs are helpers           PMAX       BGEN        DIFF
GEN 131851  NWF_NWF134.5 W   PDF=  0.7118    152.60      18.28    134.32
GEN   1147  CHEYENTA 138 S   PDF=  0.4449       -          -          -
GEN 130011  PB2SES_C13.8     PDF=  0.1098     68.00      67.88      0.12
GEN 130012  PB2SES_C13.8     PDF=  0.1098     65.00      64.88      0.12
GEN 130013  PB2SES_C13.8     PDF=  0.1098     68.00      67.88      0.12
GEN 130014  PB2SES_C13.8     PDF=  0.1098     69.00      68.88      0.12
GEN 130015  PB2SES_C13.8     PDF=  0.1098     70.00      69.87      0.13
GEN 132332  REROCK_U34.5 S   PDF=  0.0757     78.75      62.89     15.86
GEN 132333  REROCK_U34.5 S   PDF=  0.0757     78.75      62.89     15.86
GEN 181651  HOVEY_UN34.5 S   PDF=  0.0756     29.40      23.48      5.92
GEN 170200  ACA_UNIT34.5 S   PDF=  0.0732      9.99       7.98      2.01
GEN 132481  RIGGINS_34.5 S   PDF=  0.0413    150.00     119.78     30.22
GEN 132311  ECEC_G1   18     PDF= -0.0302    147.01     146.74      0.27
GEN 132312  ECEC_G2   18     PDF= -0.0302    147.01     146.74      0.27
GEN 130431  WOO_WOOD34.5 W   PDF=  0.0137     82.50       9.88     72.62
GEN 130531  WOO_WOOD34.5 W   PDF=  0.0133     77.22       9.25     67.97
GEN 131451  KEO_KEO_34.5 W   PDF=  0.0120    150.00      17.97    132.03
GEN 131455  KEO_SHRB34.5 W   PDF=  0.0120    147.50      17.67    129.83
GEN 132431  SIRIUS_U34.5 S   PDF=  0.0110    110.20      88.00     22.20
GEN 132436  SIRIUS_U34.5 S   PDF=  0.0110     50.00      39.93     10.07
GEN 130331  INDN_IND34.5 W   PDF=  0.0105     82.50       9.88     72.62
                                     |
                         mostly positives (harmers)
```

GENERATORS NEAR THE POINT OF INJECTION:

BUS#	BUS NAME	W	AR#	AREANAME	ZN#	ZONENAME	MW	PMAX	RESERV	%	mi
1147	**CHEYENTA 138**	**S**	**1**	**ONCOR_ED**	**172**	**O_WINKLE**	**0.00**	**-**	**-**	**-**	**0**
131851	NWF_NWF134.5	W	901	E_ONCOR_	993	E_WINKLE	18.31	153.	134.	12	20
130011	PB2SES_C13.8		901	E_ONCOR_	992	E_WARD	340.00	340.	0.	100	30
130321	OECCS_CT18.1		901	E_ONCOR_	977	E_ECTOR	989.53	990.	0.	100	81
131241	QALSW_GT13.8		901	E_ONCOR_	977	E_ECTOR	448.31	488.	40.	92	82
181651	HOVEY_UN34.5	S	906	E_AEP_TN	434	PECOS	23.52	29.	6.	80	84
132311	ECEC_G1 18		901	E_ONCOR_	977	E_ECTOR	294.00	294.	0.	100	88
132332	REROCK_U34.5	S	906	E_AEP_TN	986	E_PECOS	63.00	79.	16.	80	90
132333	REROCK_U34.5	S	906	E_AEP_TN	986	E_PECOS	63.00	79.	16.	80	90
132481	RIGGINS_34.5	S	906	E_AEP_TN	986	E_PECOS	120.00	150.	30.	80	122
131351	PC__PANT34.5	W	901	E_ONCOR_	980	E_HOWARD	17.10	143.	125.	12	136
131651	ELB_ELBC34.5	W	901	E_ONCOR_	980	E_HOWARD	14.24	119.	104.	12	139
130531	WOO_WOOD34.5	W	917	E_TNMP_T	986	E_PECOS	9.27	77.	68.	12	147
130431	WOO_WOOD34.5	W	906	E_AEP_TN	986	E_PECOS	9.90	83.	73.	12	151
180031	MGSES_CT13.8		901	E_ONCOR_	1166	E_MITCHE	407.00	407.	0.	100	155
132431	SIRIUS_U34.5	S	907	E_LCRATS	986	E_PECOS	88.16	110.	22.	80	156
132436	SIRIUS_U34.5	S	907	E_LCRATS	986	E_PECOS	40.00	50.	10.	80	156
132731	BOOTLE_U34.5	S	907	E_LCRATS	986	E_PECOS	93.40	117.	23.	80	157
130331	INDN_IND34.5	W	906	E_AEP_TN	986	E_PECOS	9.90	83.	73.	12	161
130221	SW_M_SW_34.5	W	906	E_AEP_TN	991	E_UPTON	9.64	80.	71.	12	162
132581	UPTON_UN34.5	S	907	E_LCRATS	991	E_UPTON	80.00	100.	20.	80	162
131451	KEO_KEO_34.5	W	917	E_TNMP_T	986	E_PECOS	18.00	150.	132.	12	166
131455	KEO_SHRB34.5	W	917	E_TNMP_T	986	E_PECOS	17.70	148.	130.	12	166
131031	INDN_IND34.5	W	906	E_AEP_TN	986	E_PECOS	10.08	84.	74.	12	167
130831	KING__KI34.5	W	906	E_AEP_TN	973	E_CRANE	9.52	79.	70.	12	168
130931	KING__KI34.5	W	906	E_AEP_TN	973	E_CRANE	4.84	40.	35.	12	168
131751	PC__PANT34.5	W	901	E_ONCOR_	980	E_HOWARD	13.86	116.	102.	12	169

Other things for consideration:

1. Are there stability or other kinds of constraints limiting ATCs?
2. If bilateral, does the receiving area also have ATC constraints*?
3. How much interaction will the POI have with nearby wind?
4. Are there future solar/wind projects that may affect yours?
5. Other other?

*See http://egpreston.com/RTS1RTS2.pdf for this subject