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COMPARISONS BETWEEN TRNSYS SOFTWARE SIMULATION AND PV F-CHART PROGRAM ON PHOTOVOLTAIC SYSTEM

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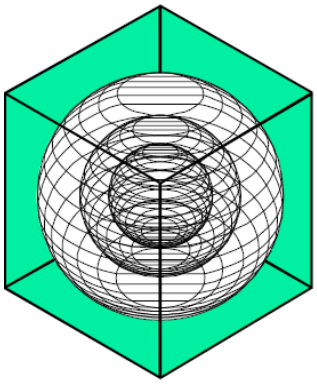

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EXECUTIVE SUMMARY

This report covers the comparisons of Photovoltaic System by TRNSYS simulation and PV F-Chart program to test TRNSYS simulation accuracy. The report starts with the Photovoltaic (PV) (PV) System introduction in Section one which is followed by Section two about the detailed simulation input and output for both TRNSYS and PVF-Chart. In Section three, the comparisons between two software are performed in terms of features and tables. Last but not least, the conclusion and references are given at the end.

For PV system, there are no different case comparisons due to the simplicity of the system without many TRNSYS components involved.

1 PHOTOVOLTAIC SYSTEM INTRODUCTION

Photovoltaic system is a system which uses PV arrays to collect solar energy and convert it into the electricity that can be used to power the equipment or be stored in energy storage devices, such as battery.

The PV system basically consists of PV arrays and inverter, shown in Figure 1-1. In the simulations of TRNSYS, the energy storage will not be considered.

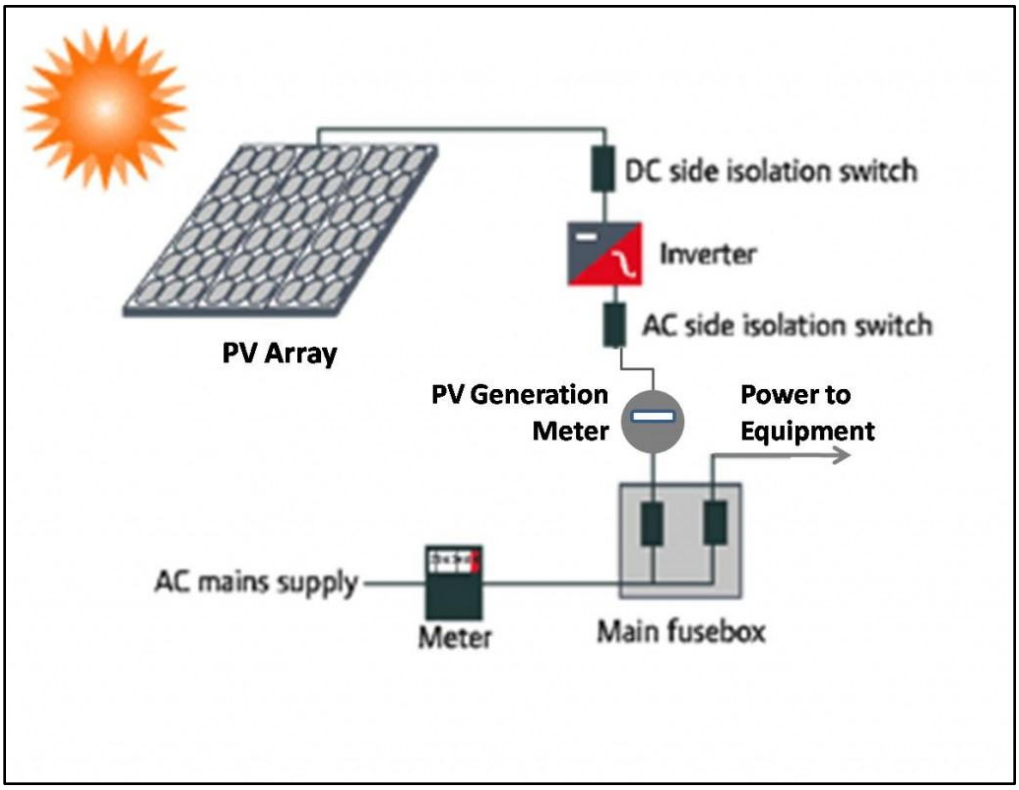

Figure 1-1 The Diagram of Photovoltaic System (*Source: http://mapawatt.com/2009/04/24/solar-pv-diagram/)*

2 PHOTOVOLTAIC SYSTEM SIMULATION

2.1 PV F-CHART Simulation

PV F-Chart is a program which can be used to simulate PV systems for design and analysis purposes. Three systems are covered by PV F-Chart, which are Utility Interface Systems, Battery Storage Systems and Systems with No Interface or Battery Storage (*PV F-Chart User's manual 2001).*

Figure 2-1 shows the utility feedback system presented in the PV F-Chart manual by using a flat-plate solar collector. In PV F-Chart simulation, the modified Houston weather is selected due to the differences existing in the weather files of TRNSYS and PV F-Chart which can be referred in Solar Domestic Hot Water System Comparison Report.

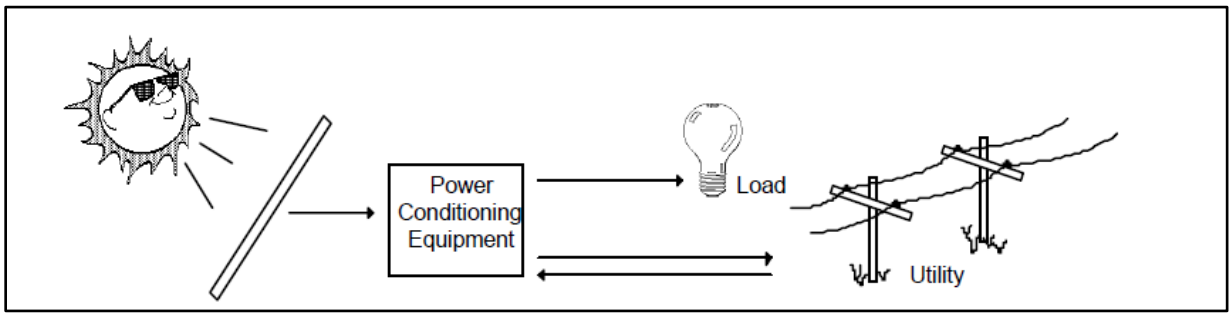

Figure 2-1 Utility Feedback System (*PV F-Chart User's manual 2001)*.

2.1.1 PV F-Chart input

Table 2-1 shows the input values for PV F-Chart Simulation. The load is set Zero for all the months, shown in Figure 2-2.

Table 2-1 F-Chart Input Values for Solar Domestic Hot Water Systems

PV F-CHART INPUT			
Utility Interface System	Location	-	Houston, TX
	Cell Temperature at NOCT Conditions	˚C	44
	Array Reference Efficiency	-	0.11
	Array Reference Temperature	˚C	25
	Array Temperature Coefficient *1000	1/◦C	4.3
	Power Tracking Efficiency	-	1
	Power Conditioning Efficiency	-	1
	% Standard Deviation of Load	%	0
	Array Area (No. of Panels X Panel	m^2	9.29
	Array Slope	degrees	40
	Array Azimuth	degrees	0

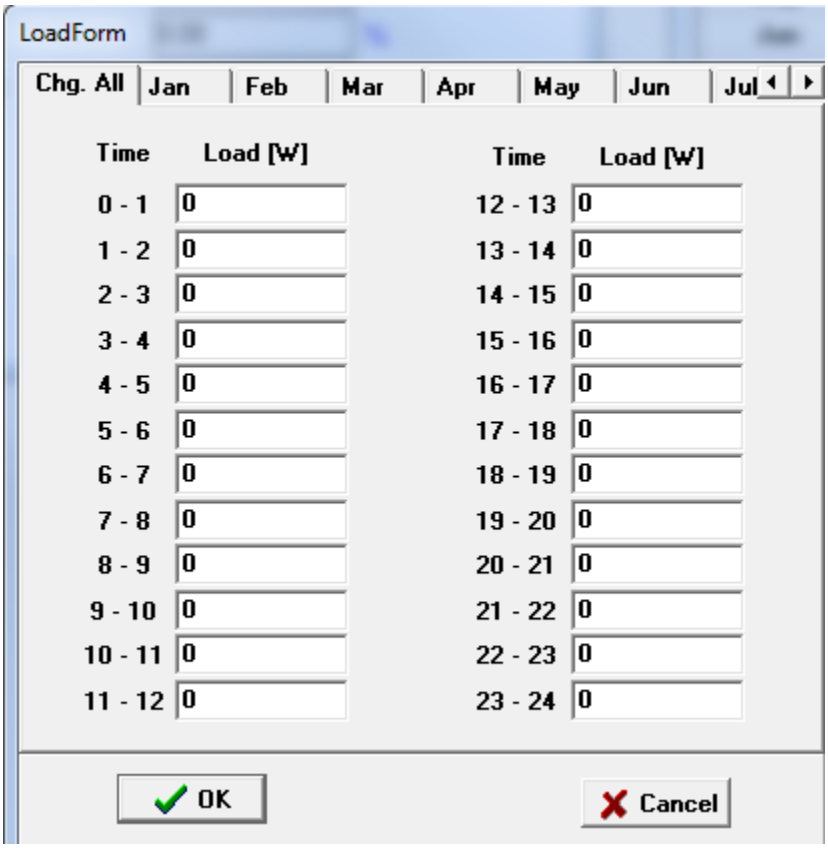

Figure 2-2 Load Settings in PV F-Chart

2.1.2 PV F-Chart output

Figure 2-3 shows the output results from PV F-Chart simulation for PV System, which includes the analysis of monthly total solar radiation (Solar), array efficiency (Efficiency), monthly total

electrical demand (Load), f factor (f), monthly total electricity sold back to the utility (Sell), monthly total electricity bought from the utility (Buy), in terms of SI unit.

System Performance Results

Summary | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

	Solar [kW-hrs]	Efficiency [%]	Load [kW-hrs]	f [%]	Sell [kW-hrs]	Buy [kW-hrs]
Jan	1043.4	10.28	0.0	100.0	107.3	0.0
Feb	1036.0	10.27	0.0	100.0	106.4	0.0
Mar	1309.7	9.91	0.0	100.0	129.7	0.0
Apr	1295.8	9.68	0.0	100.0	125.4	0.0
May	1382.6	9.48	0.0	100.0	131.1	0.0
Jun	1394.9	9.33	0.0	100.0	130.1	0.0
Jul	1418.2	9.28	0.0	100.0	131.6	0.0
Aug	1445.2	9.34	0.0	100.0	134.9	0.0
Sep	1402.2	9.46	0.0	100.0	132.6	0.0
Oct	1469.0	9.68	0.0	100.0	142.2	0.0
Nov	1187.5	9.99	0.0	100.0	118.7	0.0
Dec	950.6	10.34	0.0	100.0	98.3	0.0

Figure 2-3 PV System Output by PV F-Chart

2.2 TRNSYS Simulation

TRNSYS is a Transient System Simulation tool which can simulate not only instantaneous thermal systems but also building simulations. It is consist of simulation studio and TRNBuild as well as TRNSYS Add-ons, such as TRNFlow, COMIS 3.2, TESS Libraries and TRNSYS 3d for Google SketchUpTM (TRNSYS 17 Manual, 2010). This is user-friendly software, which provides modular image for each TRNSYS component so that the user can easily pick module graphically.

Figure 2-4 presents the TRNSYS simulation for PV system by TESS Modeling Group, which includes three main components: Weather, Solar Collector and Regulator/Invertor. The monthly data is accumulated by a force function called “MONTHLY” in the simulation.

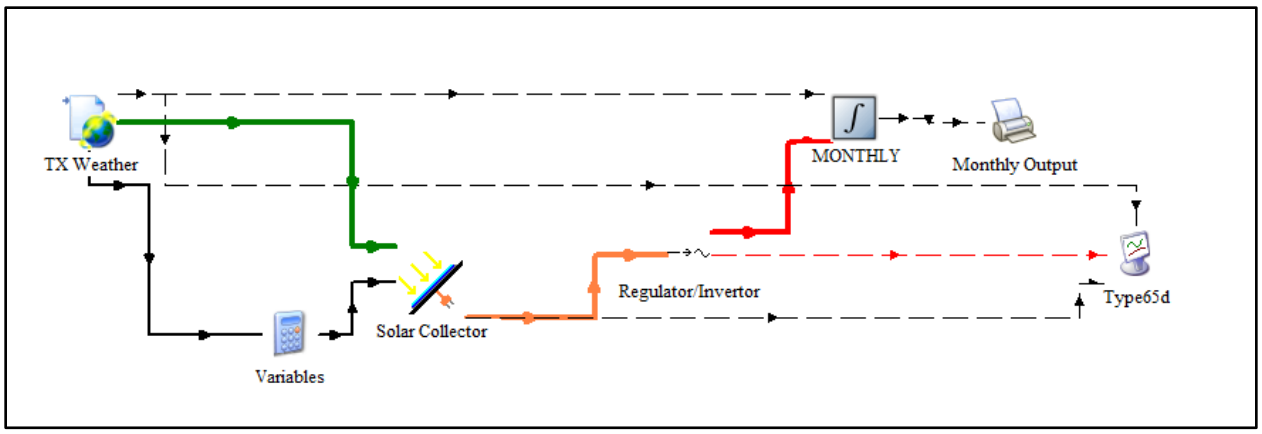

Figure 2-4 PV System Simulation by TRNSYS (*TESS Modeling Group*)

2.2.1 Weather

TMY2 Houston weather file is uploaded and its data is output by TRNSYS Type 15-2 which includes dry bulb temperature, solar radiation, humidity, etc. All the parameters are shown in Table 2-2.

Table 2-2 Weather Input Summary for Type 15-2

Parameter	Value	Unit	Remarks
File Type	2	-	2=TMY2 format
Logical Unit	35	-	The logical unit through which the data reader will read the external weather file
Tilted Surface Radiation Mode	3	-	3=Reindl Model
Ground Reflectance - no snow	0.2	-	
Ground Reflectance - snow	0.7	-	
Number of Surface	1	-	The number of surfaces for which titlted surface radiation calculations will be performed
Tracking Mode	1	-	1=fixed surface (no tracking)
Slope of Surface	40	degree	
Azimuth of Surface	0	degree	

2.2.2 Collectors

The collector is modeled by Type 562 which belongs to TESS library. This type of solar collector can be either simple glazed or unglazed photovoltaic panel. All the parameters are shown in Table 2-3.

Table 2-3 Collector Input Summary for Type 562

Parameter	Value	Unit	Remarks
PV Efficiency Mode	2	-	2=Linear modifiers for off-rated cell temperature and incident radiation
Cover Mode	0	-	0=No cover
Area	9.29	m^2	
Back Resistance	1	$h.m^2$ K/kJ	
Top Emissivity	0.9	-	
Back Emissivity	0.9	-	
Absorptance	0.9	-	
Reference PV Efficiency	0.11	-	
Reference Temperature	25	C	
Reference Radiation	3600	kJ/hr m^2	
Efficienct Modifier-Temperature	-0.004302	1/C	
Efficiency Modifier-Radiation	0	h m^2/kJ	
Input	**Value**	**Unit**	
Ambient Temperature	10	C	
Sky Temperature	10	C	
Zone Temperature	20	C	
Back Radiant temperature	20	C	
Top Heat Loss Coefficient	50	kJ/hr m^2 K	
Bottom Heat Loss Coefficient	50	kJ/hr m^2 K	
Incident Solar Radiation	0	kJ/hr m^2	

2.2.3 Regulator/Invertor

Invertor is modeled by Type 48. All the parameters are shown in Table 2-4.

Table 2-4 Invertor Input Summary for Type 48

Parameter	Value	Unit	Remark
Mode	0	-	0=Peak-power tracking collector, not battery, power is feedback to a utility
Efficiency	0.92	-	
Input	**Value**	**Unit**	**Remark**
Input Power	Linked	kJ/hr	Power from charging device
Load Power	Linked	kj?hr	Power demanded by load

2.2.4 TRNSYS Results

The monthly simulation results of TRNSYS are obtained by TRNSYS Type 24 which can integrate the value from each timestep into monthly value. Three outputs are obtained: Solar, Efficiency and Sell for PV system simulation. The detailed results of PV System are shown in Table 2-5 in term of SI unit. Compared with the results of PV F-Chart simulation shown in Figure 2-3, there are differences.

Table 2-5 TRNSYS Simulation Results in SI Unit

	TRNSYS		
	Solar (kW-hrs)	Efficiency (%)	Sell (kW-hrs)
Jan	1089.866	9.769	106.474
Feb	1079.535	9.554	103.138
Mar	1381.702	9.497	131.216
Apr	1324.884	9.358	123.988
May	1404.945	9.241	129.826
Jun	1415.276	9.075	128.436
Jul	1435.937	9.002	129.270
Aug	1459.180	8.992	131.216
Sep	1454.015	9.063	131.772
Oct	1495.337	9.128	136.498
Nov	1237.075	9.349	115.648
Dec	986.561	9.778	96.466
Year	15764.312	9.286	1463.948

3 PHOTOVOLTAIC SYSTEM SIMULATION COMPARISONS

3.1 Overview

In this section, a Solar Pool Heating System is simulated by TRNSYS software as well as PV F-Chart by using the results shown in Section 2. The comparisons of Solar, Efficiency and Sell are shown as follows.

3.2 Comparisons of TRNSYS and PV F-Chart Simulations for PV system

Figure 1-1 shows the comparisons of the monthly total solar energy incident on the PV arrays, which indicates that the patterns are quite similar. However, some points, such as from January – April and from September – December, cannot match very well. The annual difference percentage is -2.8%.

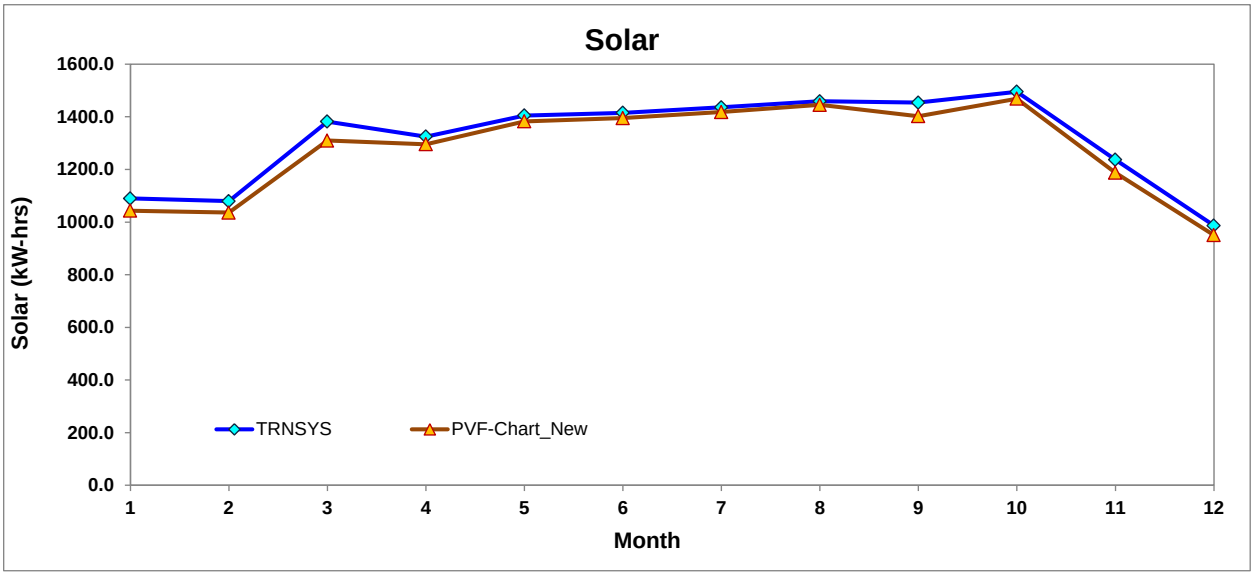

Figure 3-1 Monthly Total Solar Radiation Incident on the Collector Surface.

Figure 3-2 shows the PV array efficiency compositions, which shows a similar pattern. The efficiency for each month is quite close with a maximum difference percentage 7% occurred in February.

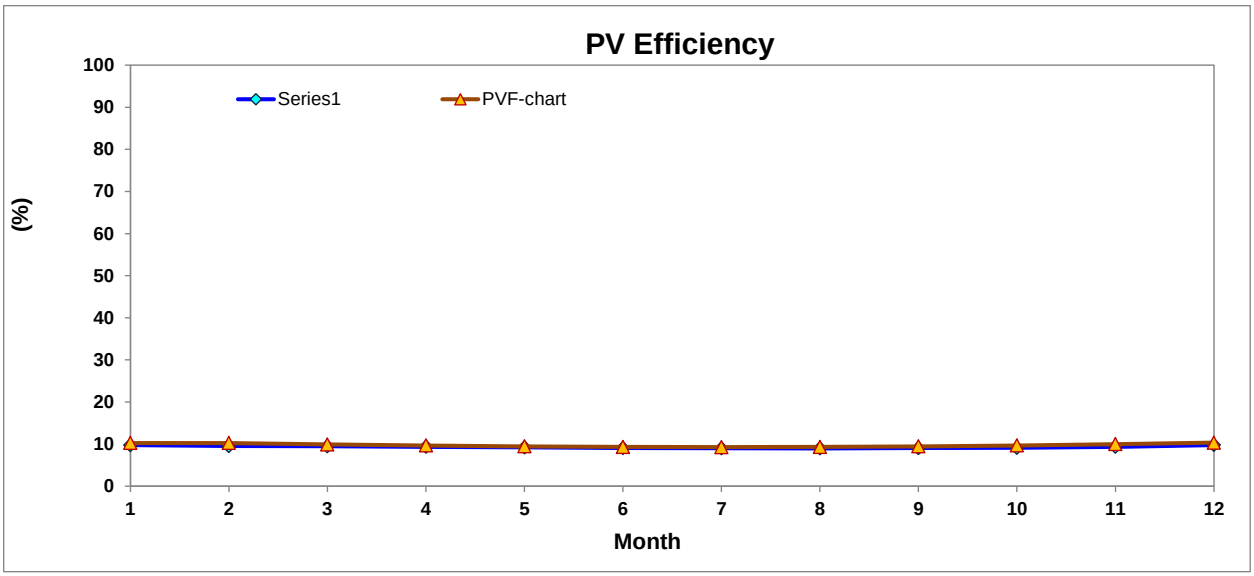

Figure 3-2 PV Efficiency

Figure 3-3 shows the monthly total electricity sold back to the utility comparisons. The two patterns are similar except certain points, such as February, August, October, etc. The annual difference percentage is 1.6%.

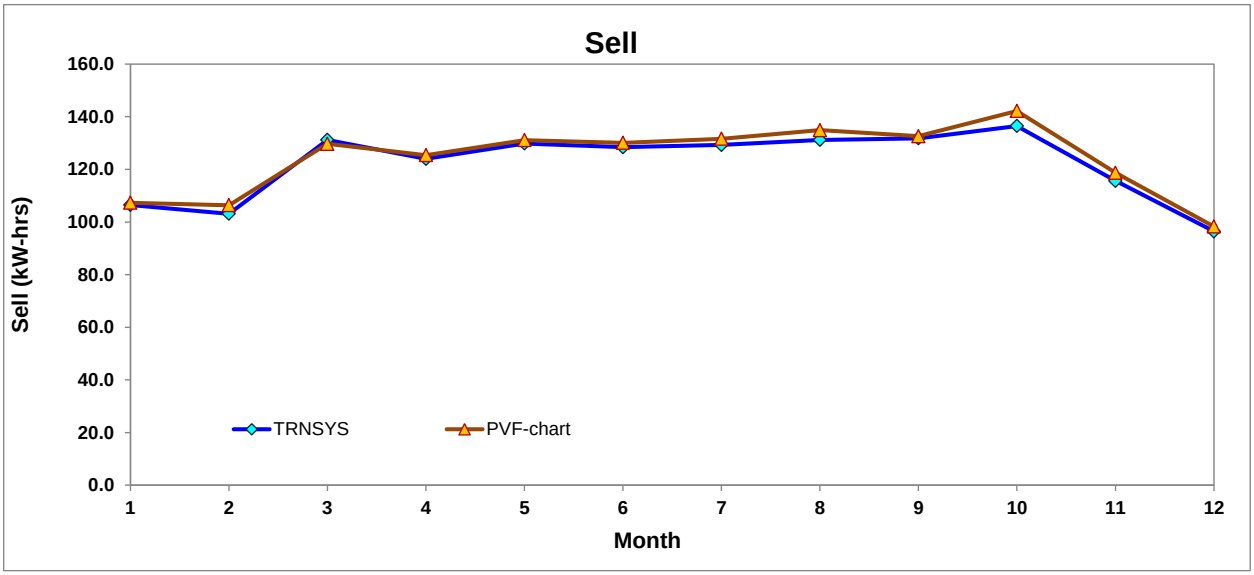

Figure 3-3 The Electricity Sold Back to Utility

Table 3-1 Comparisons Data between TRNSYS and PV F-Chart

	TRNSYS			PVF-CHART(New weather)			Diff%		
	Solar (kW-hrs)	Efficiency (%)	Sell (kW-hrs)	Solar (kW-hrs)	Efficiency (%)	Sell (kW-hrs)	Solar (%)	Efficiency (%)	Sell (%)
Jan	1089.866	9.769	106.474	1043.400	10.280	107.300	-4.5%	5.0%	0.8%
Feb	1079.535	9.554	103.138	1036.000	10.270	106.400	-4.2%	7.0%	3.1%
Mar	1381.702	9.497	131.216	1309.700	9.910	129.700	-5.5%	4.2%	-1.2%
Apr	1324.884	9.358	123.988	1295.800	9.680	125.400	-2.2%	3.3%	1.1%
May	1404.945	9.241	129.826	1382.600	9.480	131.100	-1.6%	2.5%	1.0%
Jun	1415.276	9.075	128.436	1394.900	9.330	130.100	-1.5%	2.7%	1.3%
Jul	1435.937	9.002	129.270	1418.200	9.280	131.600	-1.3%	3.0%	1.8%
Aug	1459.180	8.992	131.216	1445.200	9.340	134.900	-1.0%	3.7%	2.7%
Sep	1454.015	9.063	131.772	1402.200	9.460	132.600	-3.7%	4.2%	0.6%
Oct	1495.337	9.128	136.498	1469.000	9.680	142.200	-1.8%	5.7%	4.0%
Nov	1237.075	9.349	115.648	1187.500	9.990	118.700	-4.2%	6.4%	2.6%
Dec	986.561	9.778	96.466	950.600	10.340	98.300	-3.8%	5.4%	1.9%
Year	15764.312	9.286	1463.948	15335.100	0.000	1488.400	-2.8%		1.6%

Table 3-1 shows the details of the comparisons including the TRNSYS results, PV F-chart results by using modified Houston weather. There are differences existing between the two for each month.

4 CONCLUSION

For comparisons of PV F-Chart and TRNSYS Simulations on PV System, the results from two softwares match well on monthly results. The differences of Solar and Sell are -2.8 and 1.6%, respectively.

Therefore, the PV system model by TESS modeling group can be used in IC3 development.

5 REFERENCE

S.A., Klein and W.A., Beckman, 2001,PV F-Chart User's Manual. F-Chart Software.

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J.S., Haberl and S. Cho, 2004. Literature review of Uncertainty of Analysis Methods (PV F-Chart Program). Report #ESL-TR-04/10-02, Energy System Lab, Energy Systems Lab.