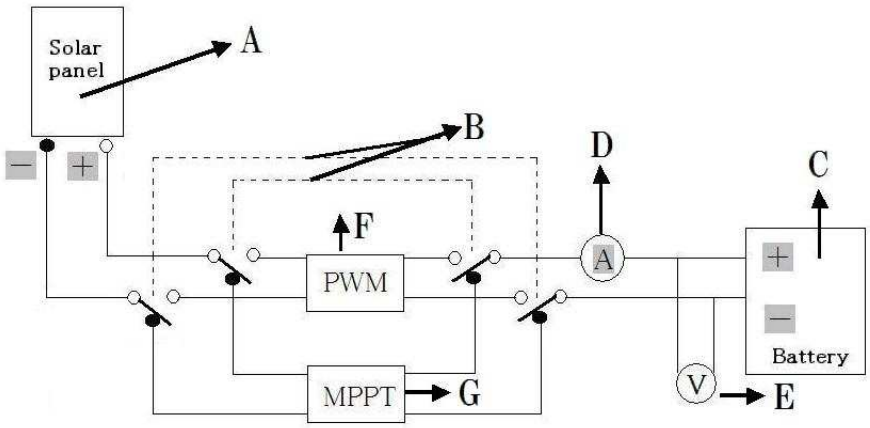
Comparison test between MPPT and PWM charger for solar generation

Day and place: April 10, 2011 (Sunday) in Toyama Prefecture, Tonami Plain, at farmyard

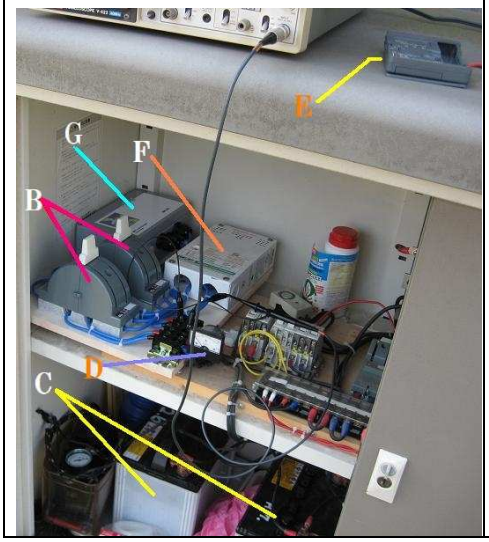
Period and Weather: 10am – 14pm Fine Noon 17℃ (So metime, strong wind blows)

Test circuit



Test Purpose

The purpose of this comparison test is to find the efficiency difference between PWM and MPPT charger for battery application with solar panel. The above circuit tells the same charging condition to battery for both chargers with same solar cell. Switching is made by (B) only to shorten the change time.

(A) Solar panel 	(1) Spanish made panel made on 2001. It was working for 10 years at this farmyard. During winter season, the panel is buried with snow, for 3 months. (2) Today's open voltage test (**) shows 10% voltage down. (3) At red arrow place, we set thermometer to measure, outside temp 17'C, and panel surface temp. 40℃ (4) We did not find the details of this solar panel, but we can see label showing: Mono crystal type 15cm x 15cm cell 36 pieces *Max output V 16.2V, *Max A 6.7A, 110W (25℃) Open Voltage 20.5V (we connect two panels with parallel. ** Open voltage test today:18.85V
(B) Switch area 	Red B: Exchange switch for MPPT and PWM Green G: MPPT with a **SMR500** from **Schams-Electronic** Orange F: PWM Yellow E: Volt meter to see Battery voltage Yellow C: 12V battery 2 sets (parallel) Grey D: Ampere meter (analog) Temp for this storage box was 15℃. However, MPPT battery set point was 20'C during AM, and in PM, we installed temp sensor to battery, but the small temp change did not affect charging current in this test condition.

Test during AM:

(a) From 10AM to PM13, we observed the change in Power Output, but we got same power always. This place is a flat ground, and sun rose at our head, no cloud, and temp shift was not much.

(b) Solar panel temp did not change

(c) So, we tested with black umbrella to create the clouds, to cover 1/3 area of glass panelto see how it moves, or we discharge battery into 12v for easy acceptance of charging.

On PM 13.00, environment was stable and we got following data:

Final data

	PWM			MPPT			**MPPT Efficiency up**
	A	V	(AxV)	A	V	(AV)	
Clear sky	10	13.04	130.4	10	14.10	141	8%
1/3 by umbrella	2	12	24	2	16.8	33.6	40%

∗ During under clear sky, it seems both are not so much different, but it is obvious that PWM is affected by the battery voltage. We have a feeling, if we can start battery voltage at 11V, then PWM shows 12V, while MPPT input at 14V.

∗ When it becomes cloudy, MPPT keep charge voltage without the affection by battery and this shows the efficiency at MPPT is far better than PWM.

This time test seems to be simple and not enough, but we do not have clear day always. We have cloudy days and MPPT always seeks best condition at each 8 seconds, so we decided to test more in worse condition.

Consideration to weather:

In Japan-sea counties', we have old saying, that, "Do not forget to bring umbrella with you, even you forget to bring lunch box". This means, we have a sudden rain always in such area. We are sure MPPT is suitable in such weather area. From the statistic data of various cities and towns, we have an interesting weather data. For example, Kanazawa-District of Yokohama City, the one year weather record shows:
Clear day= 199 days, Cloudy day= 107 days, Rain day= 59 days .So, the ratio between Fine, and not FINE is 54%: 46%. So, if you can increase the efficiency at such 46% area, then you have a great charging result.
(http://www2s.biglobe.ne.jp/~isomichi/frontpage.htm)

City Hitachi, Ibaragi Prefecture,: data since 1953 to 2010:
(http://www.jsdi.or.jp/~hctenso/MetData/Statis/st_weat.htm)
They have unique counting of weather forecast using past record of 63 years:
Fine day chance of over 70% is 105 days: small cloudy day chance is 19days; Cloudy day chance is 56 days Rain day is 13 days chance. (=total 180 days) So, left 185 days are not weather forecastable.
By this history, they adopt it to each day, like April 10 is 47% cloudy , 40% fine, 13% rain, so city people think April 10 is fine day without bringing umbrella. But even pacific area, where people think fine days are there, but in fact, MPPT is also needed for bad weather days.

Which you like, PWM, or MPPT or no controller?

To design MPPT controller, you need minimum 2 Printed circuit boards. One board is to get maximum generated electric power from solar cell, or wind generator, the other is to send power as max condition seeing battery health condition. So, naturally, MPPT charger is far expensive than PWM type.

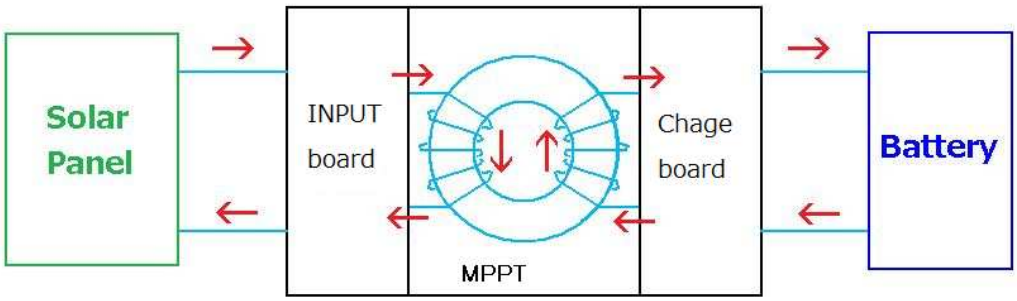
If user do not see any merit from MPPT, then he chose PWM. And if current is stable and constant charging condition is there, PWM is suitable. The merit of MPPT is found in northern cold area. In hot countries, PWM is better because condition is very stable. But regardless weather, if you try different voltage like 12, 24, 48V then one MPPT can do all work, while PWM is good for one or two only. If you have panels connected with series, like 100V, then only MPPT can do. Like telecommunication satellite, where a large battery is installed and low consumption case, we think PWM is suitable, or no charge controller needed.

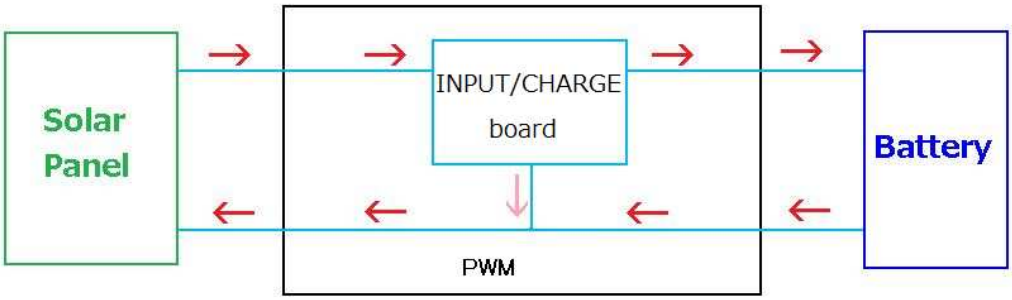
TEST date: April 15/16, 2011

Test Purpose: At the test on April 10, we did not see a big difference between MPPT, and PWM due to clear sky condition, but we found big difference by umbrella covering test method. By this condition, we felt that panel creased a max power by enough sun power so charge controller did not work so much with such good condition, so we tested again at the morning time when temperature is low.

				MPPT			PWM		
Check	Day	Time	Sky	V	A	W	V	A	W
1st	April 15	7:10	Clear	16.5V	2.5A	41.3W	12.8V	1.0A	12.8W
2nd	April 15	7:20	Clear	16.5V	2.5A	41.3W	12.8V	1.2A	15.4W
1st	April 16	7:40	Cloudy	17.5V	0.5A	8.8W	12.8V	1.2A	15.4W
2nd	April 16	7:50	Cloudy	13.6V	1.2A	16.3A	12.8V	1.2A	15.4W

In fact, the 1st time data on April 16 shows, MPPT charges less but we think sun changes rapidly which we cannot see in our eyes. However, the above result says, MPPT is not affected by the battery voltage. If we have very low voltage in battery, we think we have more clear difference between two charge controllers. This means, after 15:00PM to sunset, MPPT can work for better result. The following image is to show the circuit difference between MPPT and PWM.





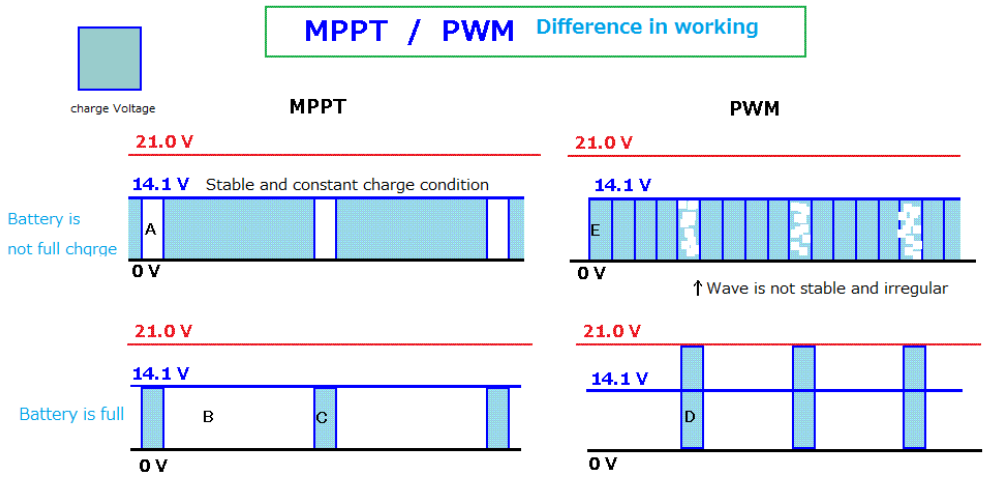
TEST date: April 17, 2011

TEST Purpose: It is clear there is a difference in the efficiency in charge power by the kind of charge controllers, but in our test, there is a limit to make another kind tests due to (1)Solar Panells are too old (over 10 years use) (2)Battery is used for 5 years. So, we decided to make another approach to find the difference in two chargers, by having DC power supply and Oscilloscope monitoring. By checking the waves from oscilloscope, we can see some new things, instead of just checking Wattage, or Volts. Unlike 10years ago solar panel voltages are many, like 22V, 35V or 42V. So, it is not necessary to think of only 12V but we can connect them in series to get high voltage (which costs less in wire transmittance). The following test was conducted and found that MPPT has new good points: We can see MPPT is a very kind electric product.

MPPT has	PWM has
Stress free equipment to others	It gives Stress to others

The new finding is not experienced if you only compare system with volt meter or ampere meter. Maybe, most of our friends in this industry thought what is difference between MPPT and PWM. ?? Price only???
This comes maybe, our test result of 8% difference by April 10 data, under clear sky condition. You may say only 8% -so what??? (but if you multiply this small value, by year to year, it becomes big, but as a figure, it is nothing so much) but if you see phenomenon via oscilloscope, by millisecond behavior, you will find big difference in both systems: The idea was, You find very good price solar panel, having output of 21V but your battery bank is 12V.

MPPT (21VDC Power supply)	**PWM (21VDC Power supply)**
Solar side board and charge side board is separate so no burden to solar panel.	Until 14.1V (Until full battery voltage), it is the same thing like solar panel is not working fully, so solar panel gets stress. So we waste output of solar panel.
When battery is full, still MPPT works at right battery voltage while solar panel also works freely.	When battery is full, solar cell cannot work at full output so still Stress remains.
So, solar panel and battery can work at no stress, for long life. Even we give 35V as panel supply, no problem in battery charge voltage.	So, as a result, MPPT was innovated to widen the application freely.



Clean wave even battery is not full, at 14.1V.
“”A”” means, by trucking, one second stop and 8 second charge work. “”B”” means, after battery is full, charge stops but wave is clean shape and does not give bad stress to battery.

This phenomenon cannot be detected if you check only by volt and ampere meter.

We give same voltage of 21V to PWM. Max charge voltage of 14.1V is given to battery, but total circuit is connected between panel and battery, so pulse shows clean wave and dirty wave included. Charge time 4: to off time 1: so we do not use 20% for charging. When the battery is full (14.1V), PWM moves to “D” mode but this simulate 21V solar panel voltage given so solar panel gets “Stress”.
In our test, this pulse area is 20MHz, and charge voltage goes 17V, and they make constant on-off function at the ratio of 50%:50%,but when it reaches to max 21V, the ratio changes OFF=80% to reduce the voltage. PWM thus do not use full power from sun.

TEST date: April 24, 2011, Noon time

TEST Purpose: At the test of April 10, we got the result of 8% efficiency difference between 2 charge controllers, so we tried to find more reasons why such small differences, with other kinds tests. Our assumption is, if battery is at the fully charged condition, we cannot find the difference in any kind chargers. So, this time test was made by using DC-AC inverter which discharged the battery to have 30% remaining capacity, and at noon time, when the sun is stable, we tested the charge efficiency with 2kinds controllers. As we thought, we find a big charge power difference. MPPT charges the battery at 15.5% more power than PWM works.

Power output comparison between PWM and MPPT — with 300W bad connected

300W lamps are connectd with AC inverter 3 hours lamp on (Battery:155Ahx 2 sets)						MPP charge side			PWM charge side			
Check	Date	Weather	tage	B.Volt	time	output	current	watt	output	current	watt	
1st	24-Apr	Fine, sometime cloudy	14.0		12:00	10.85 V	6.40 A	69.4 W	11.07 V	4.40 A	48.7 W	300W bad connected
2nd				11.24 V		10.74 V	7.80 A	83.8 W	10.79 V	7.50 A	80.9 W	
3rd						10.38 V	8.80 A	91.3 W	10.35 V	5.80 A	60.0 W	
average						10.66 V	7.67 A	81.5 W	10.74 V	5.90 A	63.2 W	
1st	24-Apr	Fine, sometime cloudy	14.0			10.70 V	7.90 A	84.5 W	10.72 V	6.90 A	74.0 W	
2nd						13.00 V	10.30 A	133.9 W	13.00 V	9.40 A	122.2 W	Inverter cut output so bad disconnected
3rd						13.36 V	13.90 A	185.7 W	13.35 V	11.20 A	149.5 W	
average						12.35 V	10.70 A	134.7 W	12.36 V	9.17 A	115.2 W	
1st	24-Apr	Fine, sometime cloudy	14.0			13.32 V	12.50 A	166.5 W	13.32 V	11.30 A	150.5 W	
2nd						13.35 V	13.50 A	180.2 W	13.35 V	11.20 A	149.5 W	
3rd						13.12 V	6.00 A	78.7 W	12.88 V	4.00 A	51.5 W	
average						13.26 V	10.67 A	141.8 W	13.18 V	8.83 A	117.2 W	
1st	24-Apr	Fine, sometime cloudy	14.0			13.31 V	10.20 A	135.8 W	13.23 V	8.60 A	113.8 W	
2ns					12:30	13.23 V	9.40 A	124.4 W	13.32 V	9.00 A	119.9 W	
average						13.27 V	9.80 A	130.1 W	13.28 V	8.80 A	116.8 W	
								122.82675			103.1161667	
						average		122W			103W	
						efficiency		115.50%			100%	

However, to reach above test, we tried before following test.

Early morning test or PM 3 test. Fine day: Sun power changes rapidly so no stable test possible.

Small rain day: We found small generation, but no stable environment, so not good for test

Noon time, cloudy: Cloud moves rapidly so no good test condition for comparison

DC power supply test (on April 17) is the simulation for sun energy-stable condition, and April 24 test is by having battery empty, the charger can work easily. In this market, people used to say that they cannot find the clear difference in MPPT and PWM, and we felt, the difference is clearly seen under stable sun condition with healthy battery function. You cannot find the difference only short time test.

Thank you for your reading

May 2011 by IZUMI CORPORATION, Hakusan City , Ishikawa, Japan