Performance Analysis of Low Lighting Systems: A Study on Operational Effectiveness

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ABSTRACT

This study is intended to evaluate the system operation effect of physical and chemical battery-based energy-independent low lighting system which is optimized for solar charging system by battery type depending on seasonal and climatic condition. All of 3 types of battery systems which are solar-charged at daytime proved to be useful at nighttime. The capacitor only system was turned off at night because of insufficient charge during rainy day, but when it comes to the Capacitor and Lead system and the Capacitor and Li-ion system were able to keep lighting at nighttime using the Lead/Li-ion capacitor even after the capacitor which had not been fully charged due to rain was fully discharged.

Keywords*: road lighting system, low lighting system, energy-independent, capacitor battery, hybrid battery*

I. INTRODUCTION

Given the drivers obtain more than 90% of the necessary information while driving the vehicle by viewing, road lighting system makes commitment to securing the visibility and reducing the traffic accident at night.

Existing light pole type is designed to irradiate the light to road surface from the high capacity light source at higher level which produces the lump of the light at the multi-level crossing, interfering with driver's view. Furthermore, wrong lighting design causes the energy consumption as well as light pollution that serves the cause of destructing the ecosystem.

Since the climatic change convention was adopted at the Conference of Parties 21 (Dec 12, 2015), energy environment has been emerged as the most critical issue worldwide. Particularly, Korea is obliged to reduce the green gas emission by 27% till 2030 from 2012, which is the highest level among the nations and thus the measure to reduce the power consumption and CO2 on road using the new and renewable energy needs to be implemented.

This study is aimed at ensuring the change of paradigm of existing lighting system, enhanced charge efficiency and power supply stability and easy maintenance and to that end, development of physical and chemical battery-based energy-independent low lighting systemwhich is optimized for solar charging system and hybrid battery system and identification of field applicability through the comparison among the systems at test bed installed within KICT were made.

II. ENERGY-INDEPENDENT LOW LIGHTING SYSTEM

2.1 Summary of energy independent low lighting system

Energy-independent low lighting system is designed to control the lighting with the solar-generated power alone, comprising of solar power generator, battery, power control system and line lighting system. Solar panel is declined at 50 degree considering the seasonal deviation in solar power generation.

Figure 1: Low lighting system(left:daytime, right:nighttime)

2.2 Summary and specification of battery system

Battery system comprises the capacitor-only system and two hybrid systems and thus total 3 types of battery system were installed at test bed and the configuration by type is as Table below.

Table 1. Composition of battery

Category		Capacitor	Capacitor + LEAD	Capacitor + Li-ion
Physical cell(Capacitor)		Capacitor(3400F)*12	3000F*10	3000F*10
Chemical cell		-	12V, 7.2Ah*2	14.8V, 10.4Ah*1
Capacity(Wh)		43	200	185
Rated voltage(V)	Physical cell	34.2~6	27	27
	Chemical cell	-	12	14.8
Size(mm)		1,020(L)*132(H)*61(W)	1,120(L)*132(H)*70(W)	1,030(L)*132(H)*70(W)
Weight(kg)		6.5	10.4	6.2
Lifespan		Over 10 years	Over 5 years	Over 5 years

III. Evaluation of system operation by type of the battery

3.1 Evaluation period by type of battery

To evaluate the system operation effect by type of battery, 4 days in winter and 6 days in spring were selected and the weather was as Table 1. Weather data was obtained fromMeteorological Office in Seoul which is the nearest one to the test bed. Mean cloud amount was 1 to 10.

Table 2. Weather data of evaluation period

Date	Weather	Mean temperature (Celsius)	Mean amount of clouds	Amount of precipitation(mm)
1/14	Clear(partly cloudy)	-3.4	4.0	-
1/15	Clear(partly cloudy)	-0.4	3.1	-
1/16	Cloudy	-0.2	7.1	-
1/17	Cloudy	1.7	6.6	-
4/24	Clear(partly cloudy)	15.5	2.3	-
4/25	Clear	17.2	0.8	-
4/26	Cloudy	21.1	5.9	-
4/27	Cloudy	17.2	9.6	-
5/2	Rain	21.1	7.0	16.5
5/3	Rain	12.9	10.0	27.0

3.2 Evaluation of system operation effect by season and type of battery

Based on data obtained from 4 days under similar conditions (Jan 14 ~ 17 and Apr 24 ~ 27, 2016), charge & discharge rate of 3 different types of battery at mean temperature and the usability as the power supply means for a low lighting system were evaluated as seen in Fig 2 ~ 4.

A Capacitor only system could be fully charged in 3 to 4 hours in a fine day during winter and in 7 hours in a cloudy days which were sufficient to keep lighting for 13 hours and 30 minutes at night (6PM till 7:30 AM) When it comes to Capacitor + LEAD system and Capacitor + Li-ion system, 3 to 4 hours were sufficient in afine day and 5 hours in a cloudy day to fully charge the capacitor and then LEAD and Li-ion capacitor, which is able to keep lighting at night for 13 hours (6PM till 7AM) by using capacitor for 7 hours and 30 minutes and LEAD/Li-ion capacitor for 6 hours.

A Capacitor only system could be fully charged in 2 hours in a fine day during spring and in 6 hours in a cloudy days which were sufficient to keep lighting for 10 hours and 30 minutes at night (7:30PM till 5:30 AM) When it comes to Capacitor + LEAD system and Capacitor + Li-ion system, 2 hours were sufficient in afine day and 5 hours in a cloudy day to fully charge the capacitor and then LEAD and Li-ion capacitor, which is able to keep lighting at night for 10 hours (7:30PM till 5:30AM) by using capacitor for 7 hours and 30 minutes and LEAD/Li-ion capacitor for 2 hours and 30 minutes.

Viewing the above, mean temperature by season appeared not to have influenced on battery system and energy-independent low lighting system would possibly be used during winter when longer lighting hours are required. However the data when temperature is further lower(over -10 degrees celsius) seems to be needed.

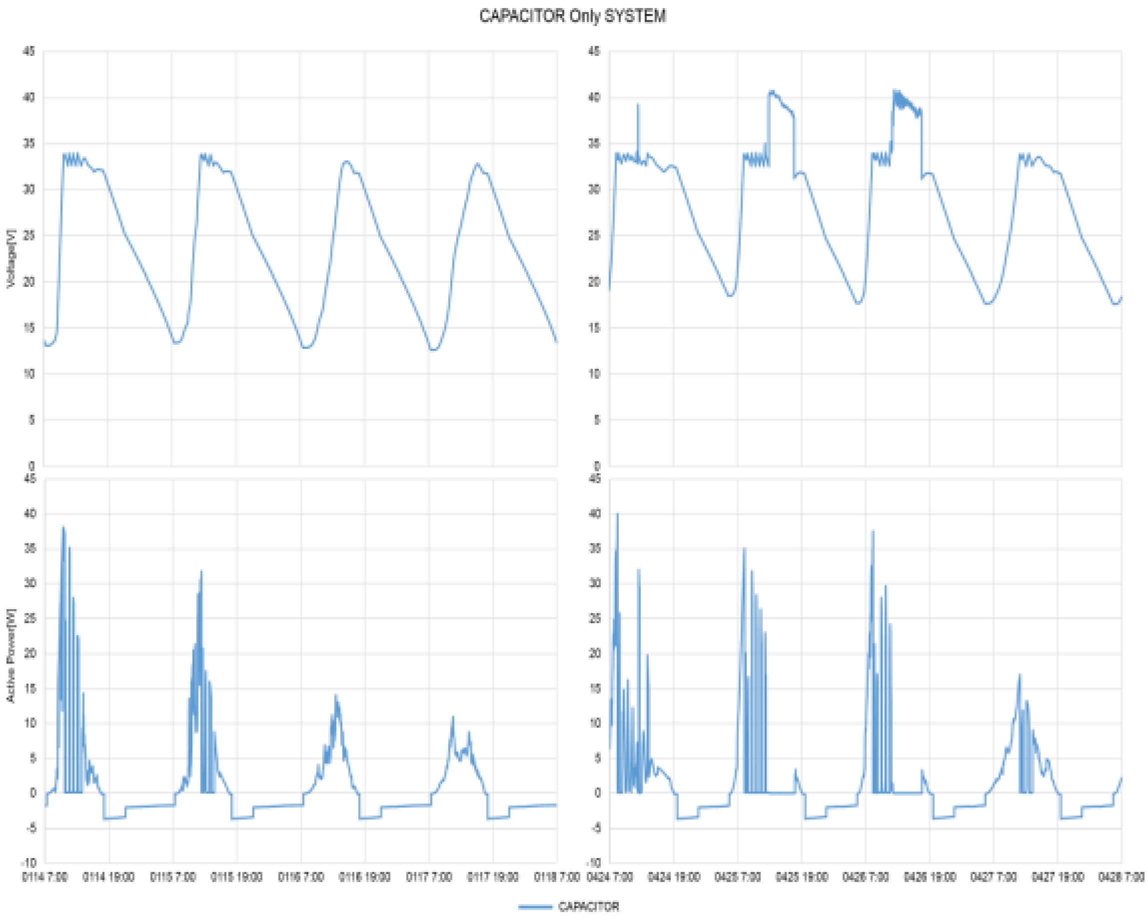

Figure 2: Evaluation of CAPACITOR Only System by season

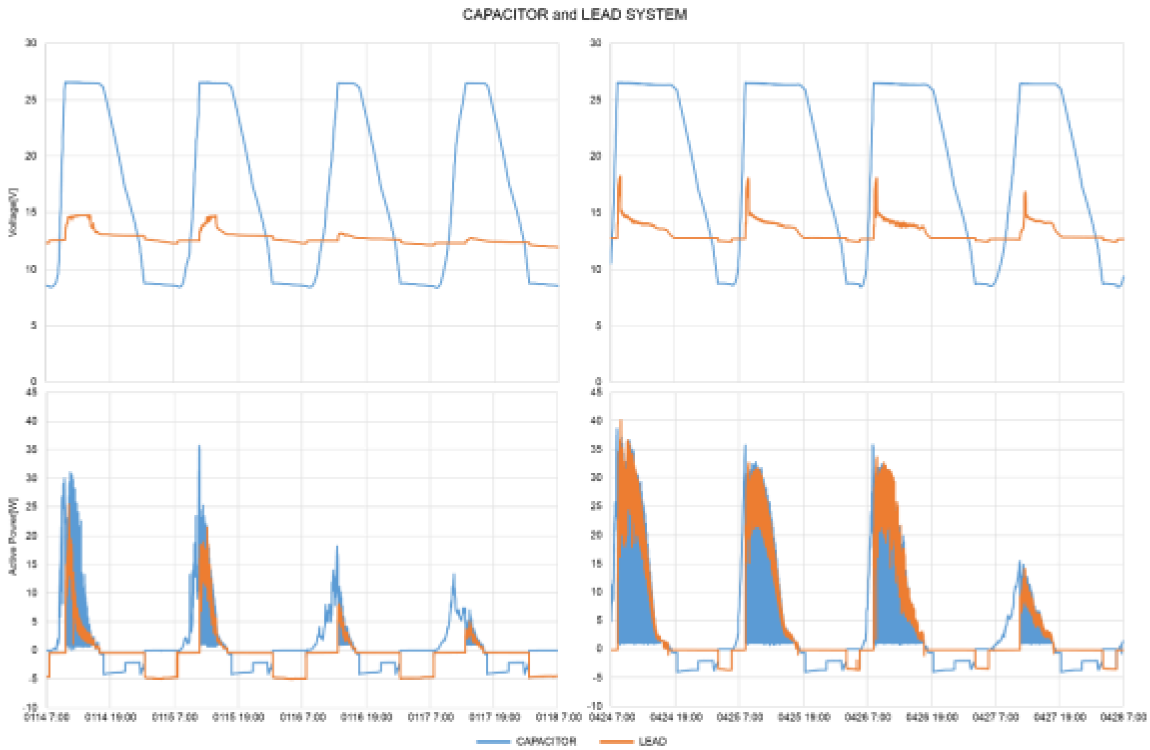

Figure 3: Evaluation of CAPACITOR and LEAD System by season

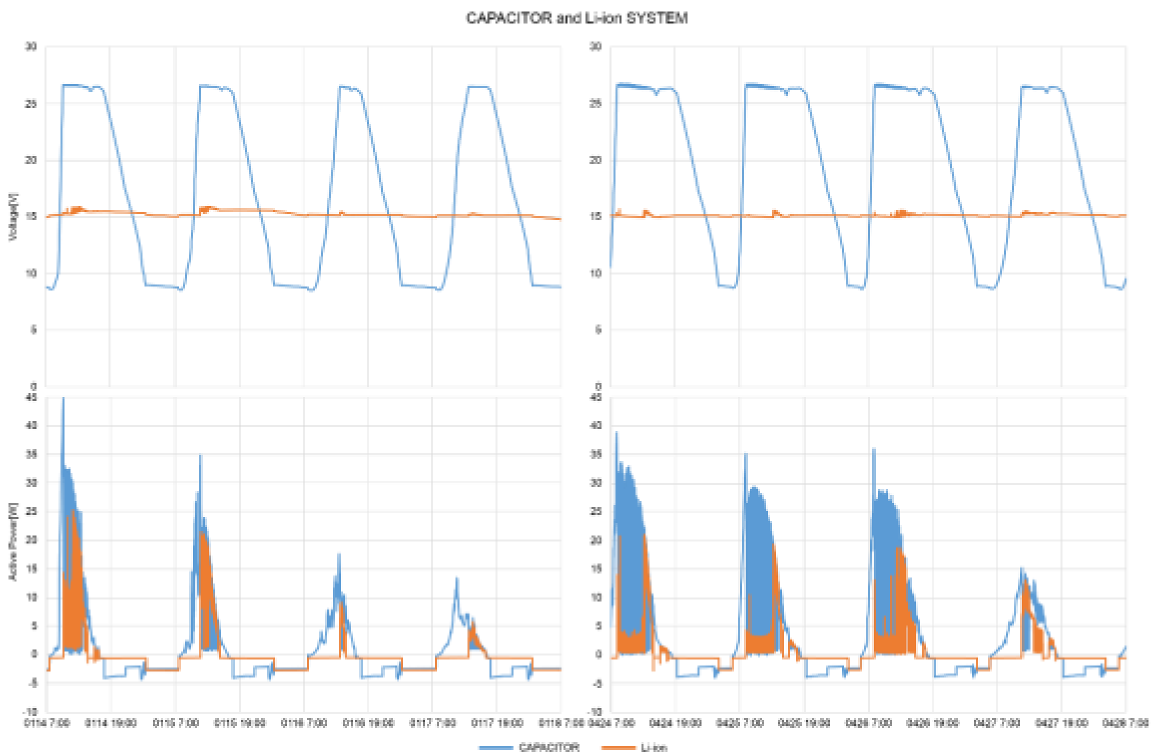

Figure 4: Evaluation of CAPACITOR and Li-ion System by season

3.3 Evaluation of system operation effect by type of battery depending on weather

Based on data obtained from 2 days under similar conditions except the weather (Apr 24 ~ 25 and May 2 ~ 3, 2016), charge & discharge rate of 3 different types of battery depending on weather and the usability as the power supply

means for a low lighting system were evaluated as seen in Fig 5 ~ 7. What to be noted is the rain started in the afternoon of May 2.
When it comes to the capacitor only system, it's fully charged before the rain started and was able to keep lighting for 10 hours (7:30 PM till 5:30 AM) but was not fully charged on May 3 because of the rain and the lighting was discontinued at 4:30 AM.

But when it comes to Capacitor + LEAD system and Capacitor + Li-ion system, despite of incomplete chargeof the capacitor due to rain, lighting could be continued by LEAD + Li-ion capacitor even after a compete discharge of the capacitor.

Viewing the above, battery system was directly influenced by solar power generation depending on weather conditions and thus capacitor only system seems not to be able to keep operating the energy-independent low lighting system. Thus for a stable operation of energy-independent low lighting system, capacitor + LEAD system and capacitor + Li-ion system are considered appropriate.

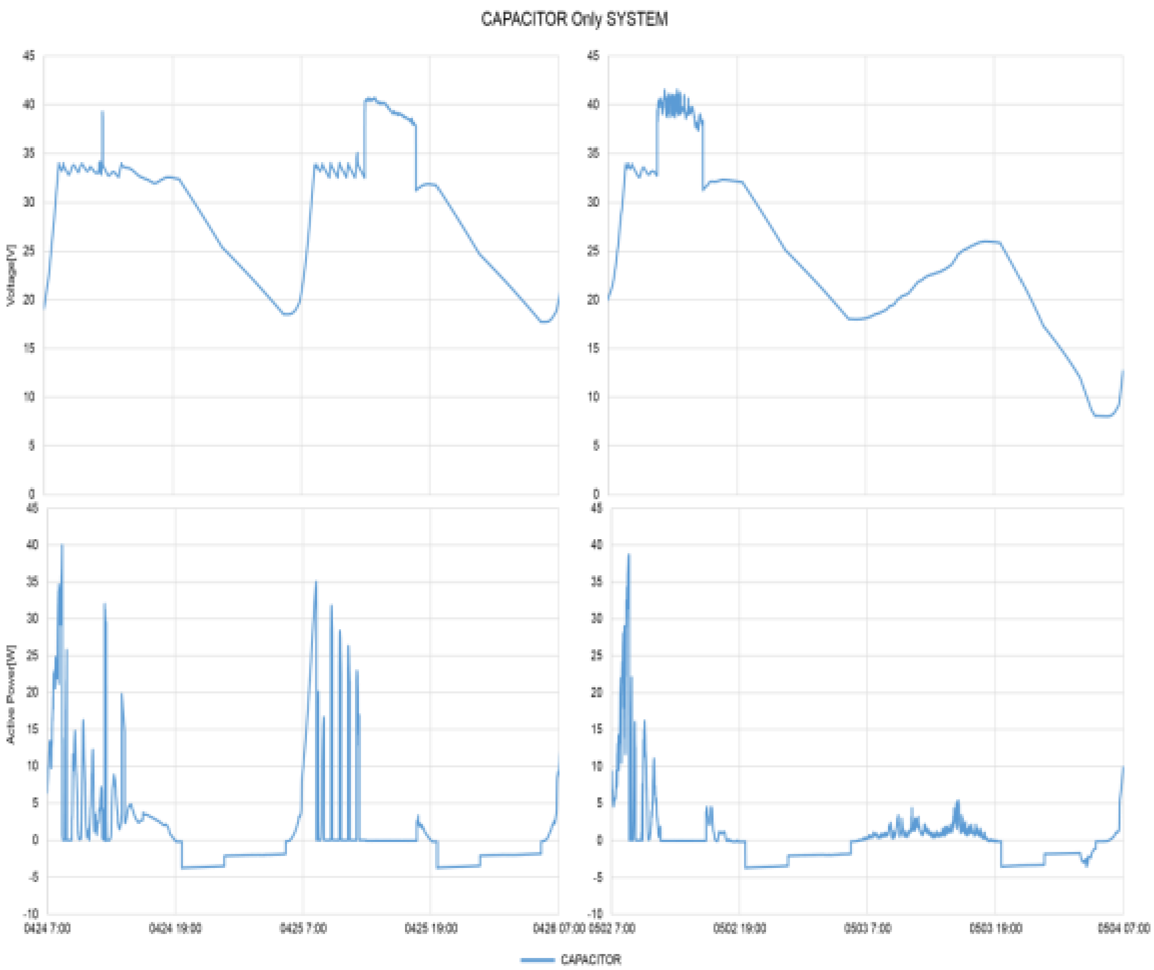

Figure 5: Evaluation of CAPACITOR Only System depending on weather

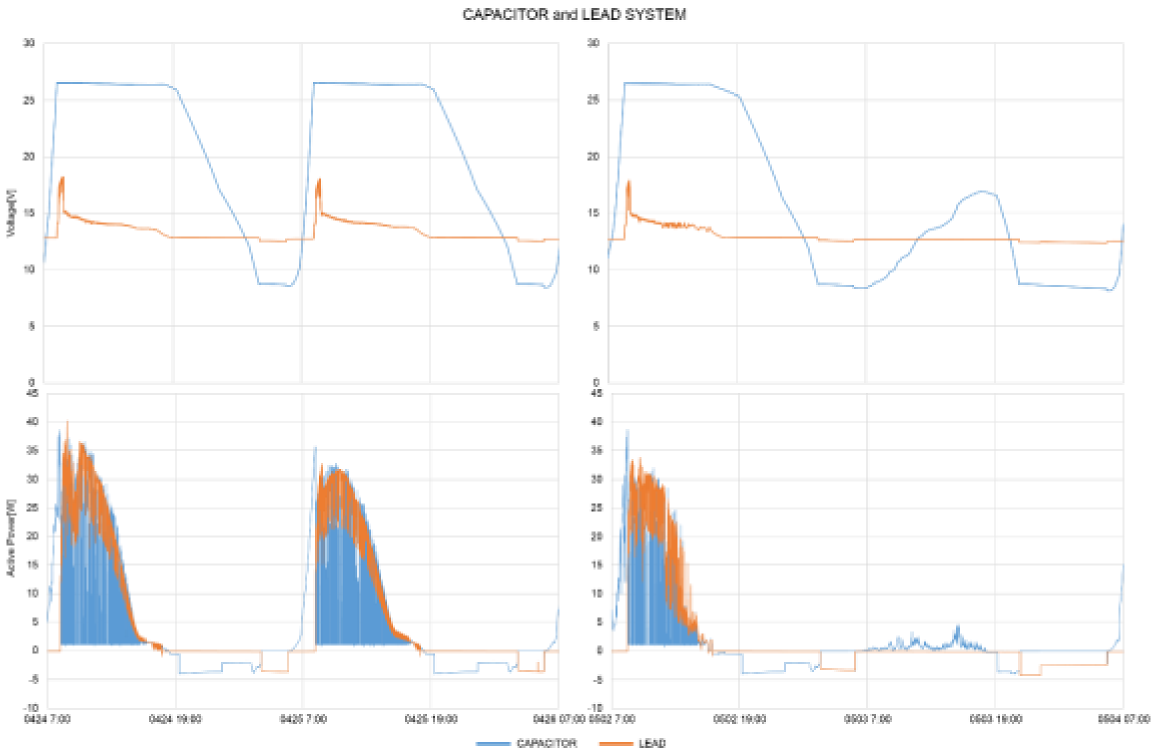

Figure 6: Evaluation of CAPACITOR and LEAD System depending on weather

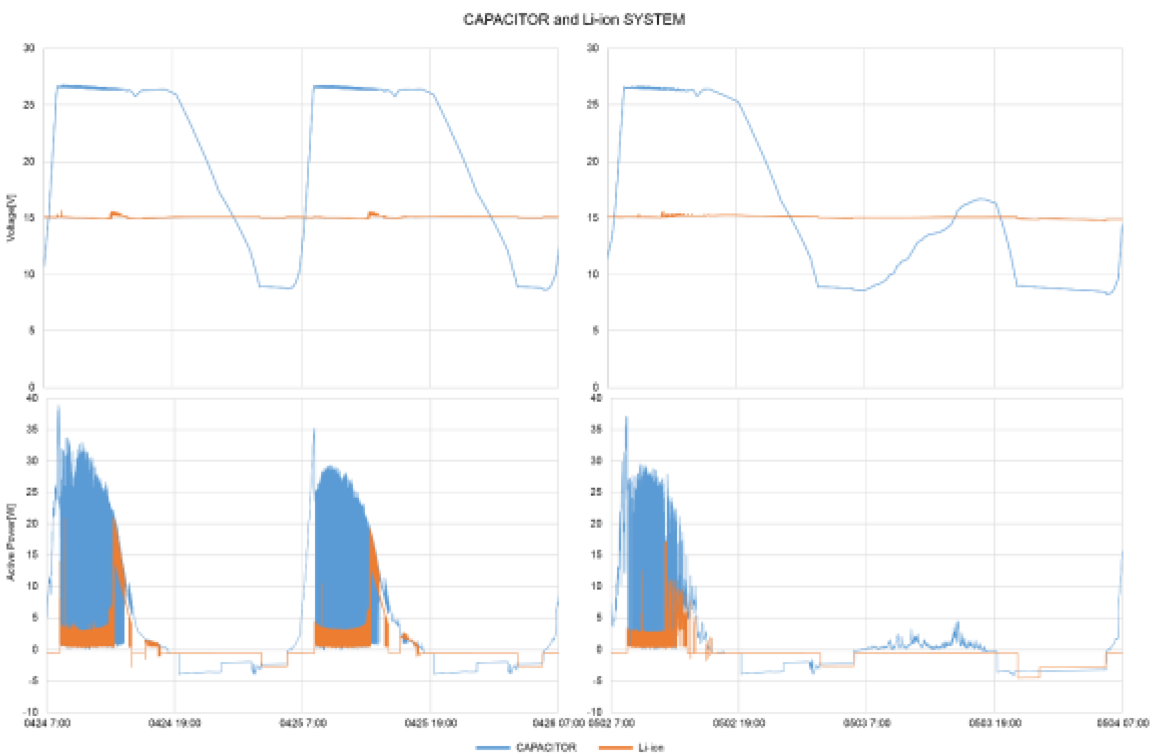

Figure 7: Evaluation of CAPACITOR and Li-ion System depending on weather

IV. CONCLUSION

This study is intended to develop the physical and chemical battery-based energy-independent low lighting system which is optimized for solar charging system and hybrid battery system as well as compare and analyze the systems at the test bed installed at KICT and consequently, the conclusion obtained is outlined as below.

- Battery system was evaluated in winter and spring, respectively. 3 different types of battery were solar charged at daytime in fine or cloudy day and were found to be operable at nighttime. A mean seasonal temperature didn't have influence on battery system but the data when temperature is further lower (over -10 degreescelsius) seems to be needed.
- Battery system was evaluated depending on weather condition, fine or cloudy. The capacitor only system was turned off at night because of insufficient charge in rainy day but capacitor +LEAD system and capacitor + Li-ion system was able to keep lighting at the night using LEAD/Li-ion capacitor even after the capacitor had been fully discharged. Thus for a stable operation of energy-independent low lighting system, capacitor + LEAD system and capacitor + Li-ion system are considered optimal.

Additionally, the study on operation of energy-independent low lighting system when sunless days continue or torrential rain continues is needed to come up with the solution to deal with.
Furthermore, the study on change to user's recognition when existing light pole type was changed to a low lighting system and on operation of energy-independent low lighting system through on-road test and monitoring to promote the use of new and renewal energy technology are required.

V. ACKNOWLEDGEMENTS

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