Power Distribution System for a CubeSat

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Contents

Objective

To design and implement a fully autonomous power generation, storage and distribution system for a CubeSat

System Architecture

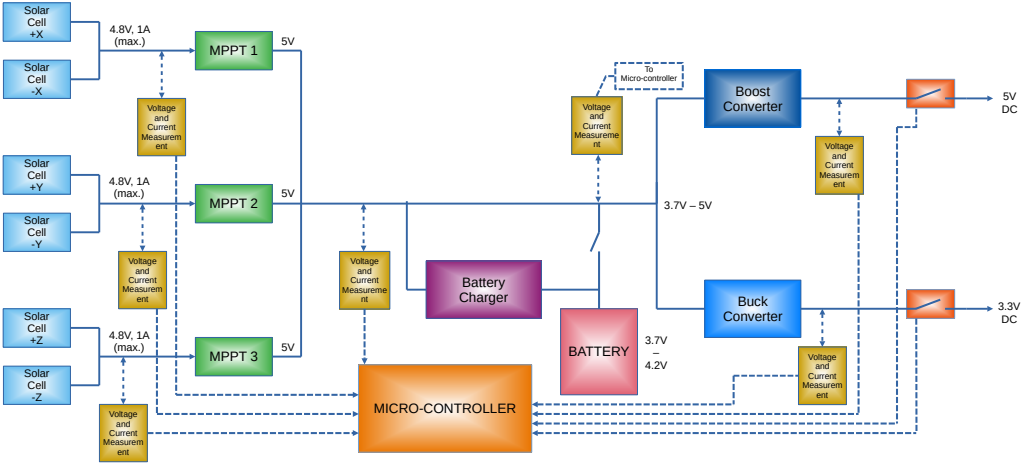

Figure 1: CubeSat EPS Architecture

Hardware Design - Buck and Boost Converters with Monitoring

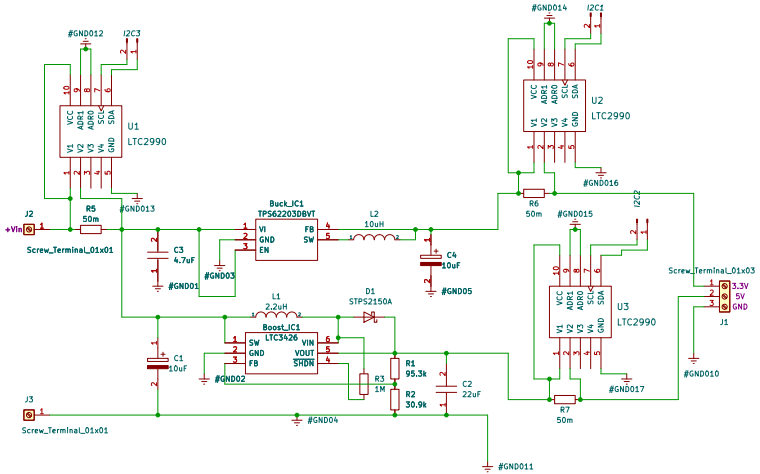

Figure 2: Circuit design of buck and boost converters with monitoring

Hardware Design - Buck and Boost Converters (Contd.)

Buck Converter:

- IC: TPS62203
- Input Voltage: 3.6 - 5V
- Output Voltage: 3.3V
- Switching Frequency: 1MHz
- Output Current: 300mA (max.)

Boost Converter:

- IC: LTC3426
- Input Voltage: 3.6 - 5V
- Output Voltage: 5V
- Switching Frequency: 1.2MHz
- Output Current: 500mA (max.)

All converters operate in continuous conduction mode.

Hardware Design - Buck and Boost Converters with Monitoring (Contd.)

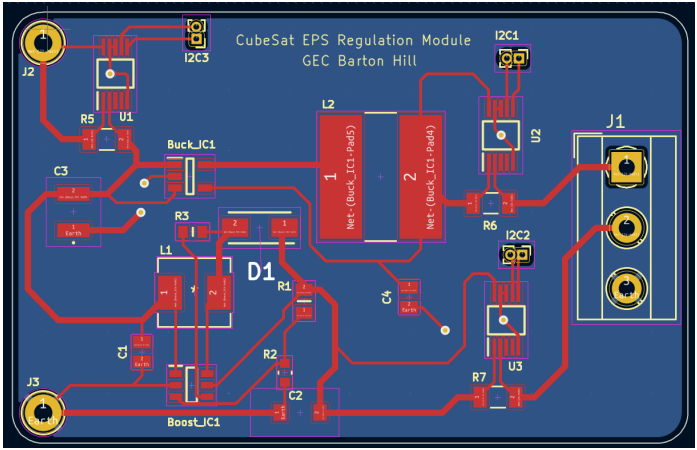

Figure 3: PCB Layout of buck and boost converters with monitoring (55mm x 35mm)

Hardware Design - Buck and Boost Converters with Monitoring (Contd.)

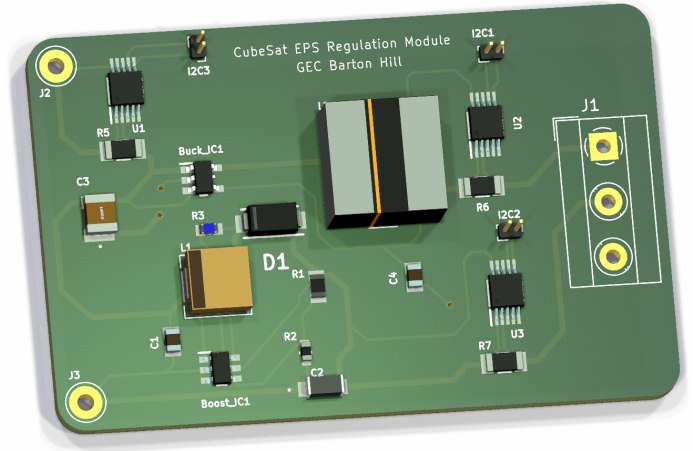

Figure 4: 3-D model of buck and boost converters with monitoring

Hardware Design - Voltage and Current monitoring IC

- IC: LTC 2990
- Quad input
- Voltage and Current Monitoring
- Communication via I2C serial interface

Hardware Design - Battery Charger

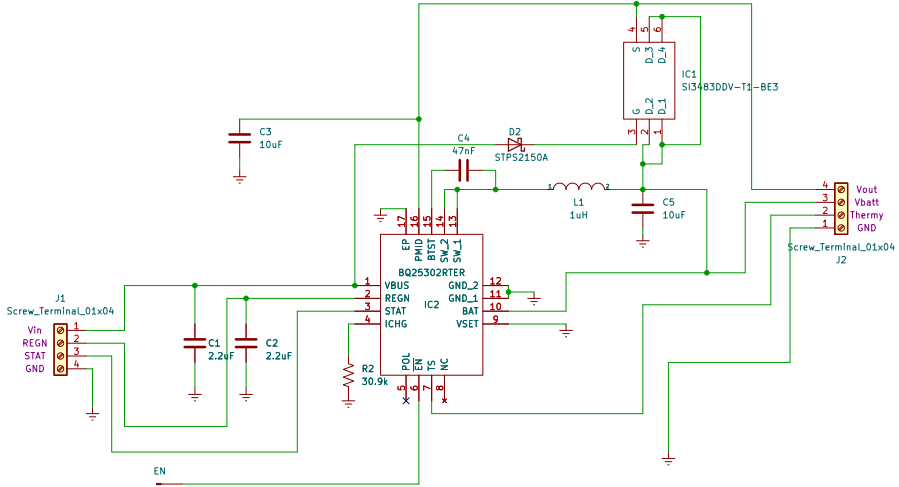

Figure 5: Circuit design of Battery Charger

Hardware Design - Battery Charger (Contd.)

Synchronous Buck Battery Charger:

- IC: BQ25302 (With External Power Path configuration)
- Input Voltage: 5V
- Output Voltage: 4.2V (max.)
- Switching Frequency: 1.2MHz
- Output Current: Limited to 1.2A
- Thermistor: Semitec 103AT-2 (10kΩ)
- Charging Temperature: Limited between 0 - 45 C
- Track width: 0.25mm
- Power Path Track width: 0.52mm

Hardware Design - Battery Charger (Contd.)

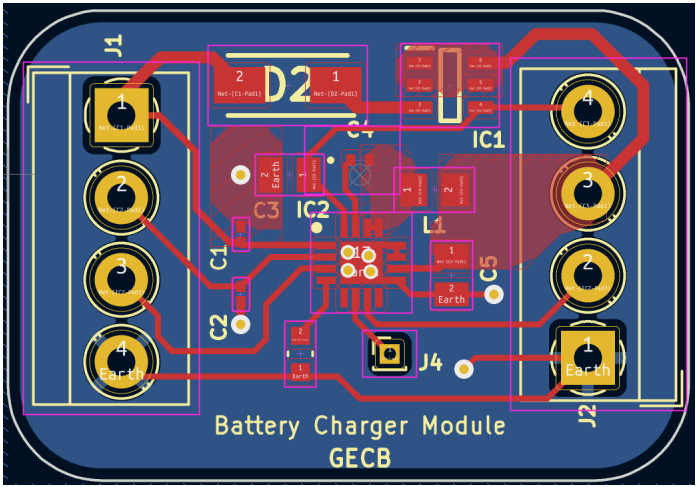

Figure 6: PCB Layout of Battery Charger (29mm x 20mm)

Hardware Design - Battery Charger (Contd.)

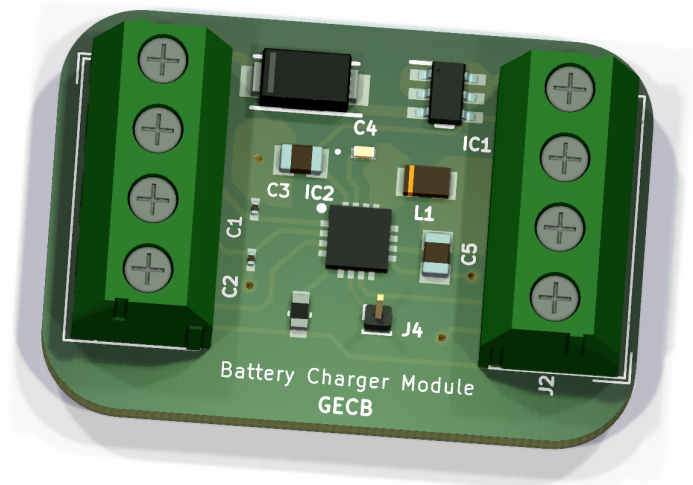

Figure 7: 3-D model of Battery Charger

Hardware Design - Maximum Peak Power Transfer (MPPT)

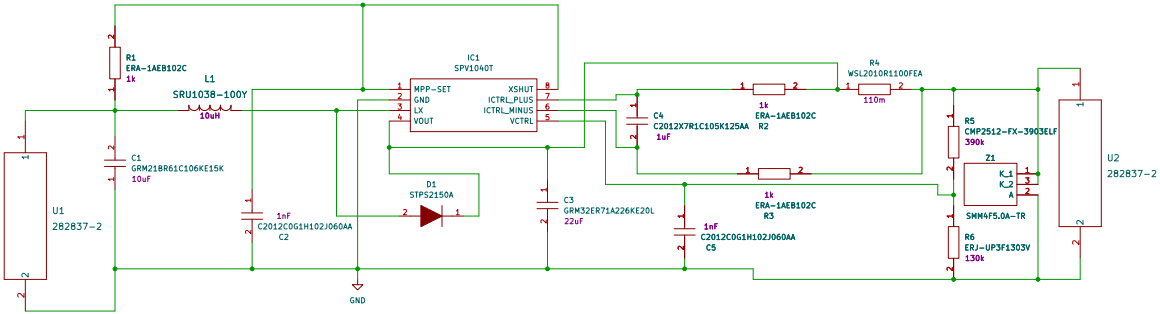

Figure 8: Circuit design of MPPT

Hardware Design - MPPT (Contd.)

- IC: SPV1040
- MPPT with Perturb and Observe algorithm
- Input Voltage: 0.3 - 5.5V
- Output Voltage: 5V
- Switching Frequency: 100kHz
- Inbuilt over-current, temperature protection
- Efficiency: 95%

Hardware Design - MPPT (Contd.)

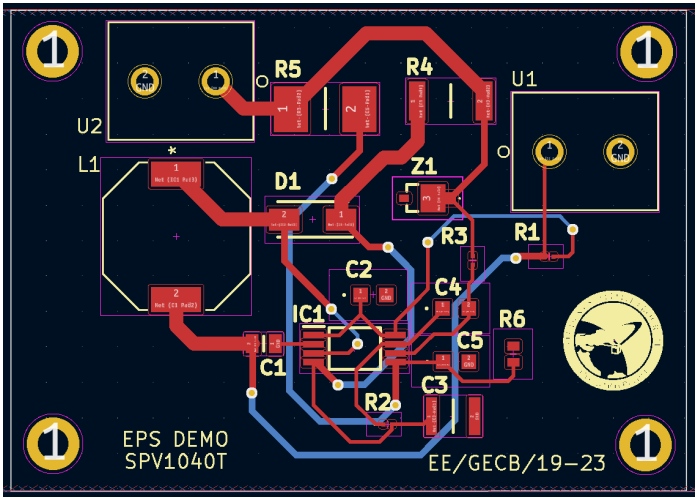

Figure 9: PCB Layout of MPPT (48mm x 34mm)

Hardware Design - MPPT (Contd.)

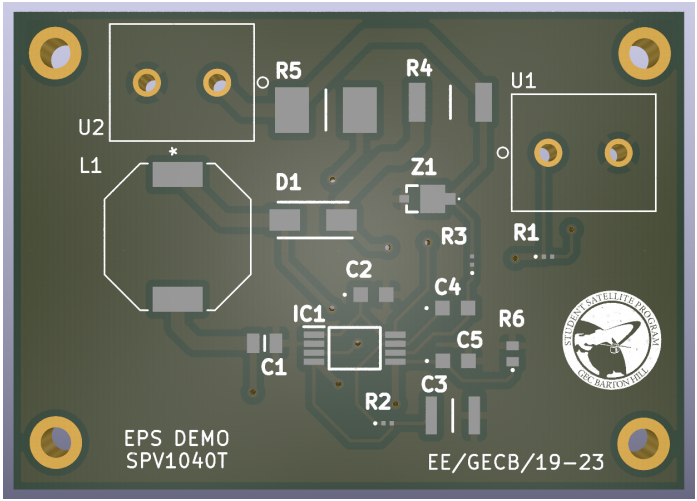

Figure 10: 3-D model of MPPT

Hardware Design - Protection

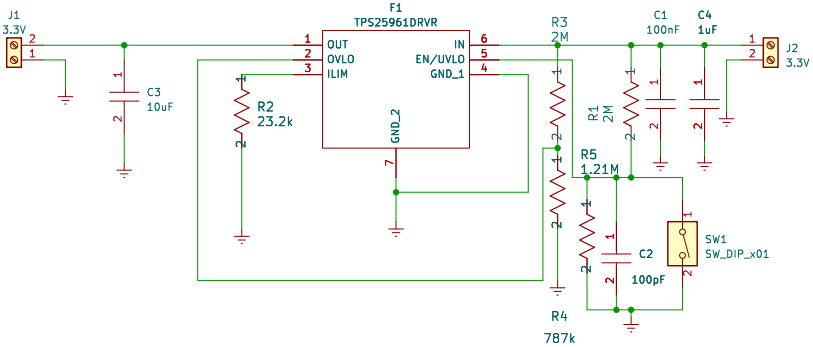

Figure 11: Circuit design for protection

Hardware Design - Protection (Contd.)

- IC: TPS25961
- Under-voltage, Over-voltage, Short circuit, Over-current, Over-temperature protection
- Input Voltage Range: 0.3 - 21V
- Maximum Output Voltage: $V_{in} + 0.3$
- Temperature Range of -40°C - 125°C
- Adjustable current limit threshold from 0.1A - 2A.

Hardware Design - Protection (Contd.)

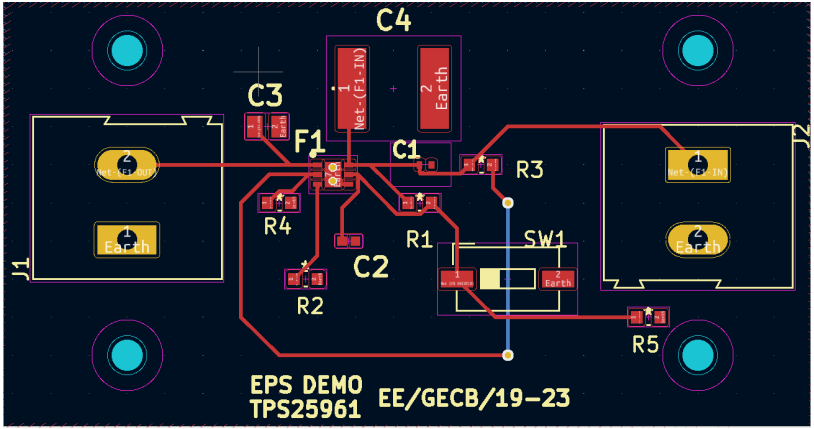

Figure 12: PCB Layout of protection circuit (55mm x 28mm)

Hardware Design - Protection (Contd.)

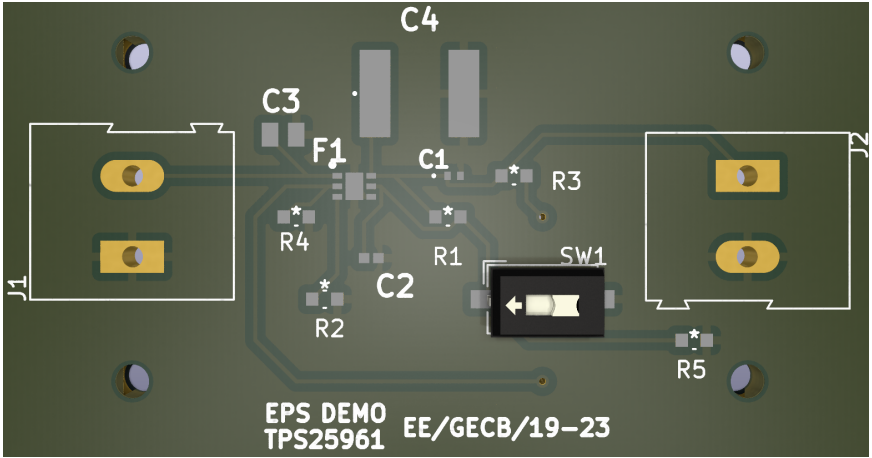

Figure 13: 3-D model of protection circuit

Components List

Sl NO.	MANUFACTURER PART#	DESCRIPTION	QUANTITY
1	C1210C475K4RACAUTO	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 4.7uF X7R 1210 10% AEC-Q200	4
2	ERA-1AEB102C	Thin Film Resistors - SMD 0201 1Kohm 0.1% 25ppm	10
3	C2012X7R1C105K125AA	Multilayer Ceramic Capacitors MLCC - SMD/SMT 1.0UF 16V 10% 0805	4
4	MCT0603MD1004BP500	Thin Film Resistors - SMD .125W 1Mohms .1% 0603 25ppm	4
5	WSL2010R1100FEA	Current Sense Resistors - SMD 1/2watt .11ohms 1%	4
6	SI3483DDV-T1-BE3	MOSFET P-CHANNEL 30-V (D-S)	4
7	CMP2512-FX-3903ELF	Thick Film Resistors - SMD ResHighPower 2512 390k 1% 1.5W TC100	4
8	C2012C0G1H102J060AA	Multilayer Ceramic Capacitors MLCC - SMD/SMT	6
9	ERJ-PB6B3002V	Thick Film Resistors - SMD 0805 Anti-Surge Res. 0.1%, 30Kohm	4
10	GRM32ER71A226KE20L	Multilayer Ceramic Capacitors MLCC - SMD/SMT	4
11	GRM21BR61C106KE15K	Multilayer Ceramic Capacitors MLCC - SMD/SMT 10UF 16V 10% 0805	10
12	ERJ-UP3F1303V	Thick Film Resistors - SMD 0603 Anti-sulfurated anti-surge resistor	4
13	CL03A225KP3CRNC	Multilayer Ceramic Capacitors MLCC - SMD/SMT X5R, 2.2uF, +/-10%, 10v, 0201	6
14	0805YC106KAT2A	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 10uF X7R 0805 10%	11
15	RC0603FR-0730K9L	Thick Film Resistors - SMD 30.9 kOhms 100mW 0603 1%	7
16	SRN1060-100M	Power Inductors - SMD 10uH 20% SMD 1060	4
17	IHLP2020CZER2R2M8A	Power Inductors - SMD 2.2uH 6.6A 26Mohm	5
18	C1005X8R1C473M050BB	Multilayer Ceramic Capacitors MLCC - SMD/SMT	10
19	LTC3426ES6#TRMPBF	Switching Voltage Regulators 1.2MHz Boost DC/DC Conv in SOT-23	3
20	SPV1040T	Battery Management Hi efficiency solar battery charger	3
21	CR0805-FX-9532ELF	Thick Film Resistors - SMD 95.3K 1%	5
22	WSLP1206R0500FEA	Current Sense Resistors - SMD 1Watt 0.05Ohms 1%	10
23	C3216JB1C226M160AB	Multilayer Ceramic Capacitors MLCC - SMD/SMT	4
24	STPS2150A	Schottky Diodes & Rectifiers 2.0 Amp 150 Volt	5
25	SRU1038-100Y	Power Inductors - SMD 10uH 30% SMD 1038	4
26	IHHP0805ZHER1R0M01	Power Inductors - SMD 0805 1uH 20%	4
27	LTC2990CMS#PBF	I2C V, C & Temp Mon	3
28	LTC4361CDC-2#TRMPBF	Overvoltage/Overcurrent Prot Cntr	3
29	TPS62203DBVT	Switching Voltage Regulators 3.3V Out Hi-Eff Step-Down Converter	3
30	BQ25302RTER	Li ion Battery Charger	3
31	511-SMM4F5.0	ESD Suppressors / TVS Diodes 400W HI JCT TMP	3
32	STPS2150A	Schottky Diodes & Rectifiers 2.0 Amp 150 Volt	3

PCB Specifications

- Manufacturer: ROBU.IN
- Material: FR-4 (Flame retardant epoxy resin and glass fabric composite)
- Board Thickness: 1.6mm
- Surface finish: HASL[1](with lead)
- Finished Outer Layer Copper: 1 oz
- Finished Inner Layer Copper: 0.5 oz
- PTH[2] Via diameters: 0.8 mm, 0.6mm (For thermal)
- PTH Via hole: 0.4 mm
- No. of boards: 4 designs x 5 pcs.
- Total cost: Rs. 3096

[1] Hot Air Solder Levelling

[2] Plated Through Hole

HW Implementation

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Conclusion

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Project Timeline

Activity	Jan week 3-4	Feb week 1-2	Feb week 3-4	Mar week 1-2	Mar week 3-4	Apr week 1-2	Apr week 3-4	May week 1-3
PCB design and fabrication								
Component procurement								
Microcontroller programming								
Soldering								
Troubleshooting								
Report Writing								

References

[1] Knap, Vaclav & Vestergaard, Lars & Stroe, Daniel-Ioan (2020)
A Review of Battery Technology in CubeSats and Small Satellite Solutions
Energies, vol. 13

[2] A. Edpuganti, V. Khadkikar, H. Zeineldin, M. S. E. Moursi and M. Al Hosani (2021)
Comparison of Peak Power Tracking Based Electric Power System Architectures for CubeSats
IEEE Transactions on Industry Applications, vol. 57, no. 3, pp. 2758-2768, May-June 2021

[3] E. Ayoub and N. Karami (2015)
Review on the charging techniques of a Li-Ion battery
Third International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2015, pp. 50-55

References (Contd.)

[4] B. Hussein, A. M. Massoud and T. Khattab (2022)
Centralized, Distributed, and Module-Integrated Electric Power System Schemes in CubeSats: Performance Assessment
IEEE Access, vol. 10, pp. 55396-55407

[5] A. Edpuganti, V. Khadkikar, M. S. E. Moursi, H. Zeineldin, N. Al-Sayari and K. Al Hosani (2022)
A Comprehensive Review on CubeSat Electrical Power System Architectures
IEEE Transactions on Power Electronics, vol. 37, no. 3, pp. 3161-3177, March 2022

[6] Aulia Indana, Dharu Arseno, Edwar, and Adilla Safira (2020)
Output Power Analysis of Tel-USat Electrical Power System
AIP Conference Proceedings 2226

Thank You