Analysis of the Solar Charge Controller using ABCD Framework

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P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 1

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

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ABSTRACT

Purpose: *The renewable energy is getting more and more popular today due to various factors including the benefits of the energy system, contribution to the environment in zero pollution, and flexible adoption for both domestic as well as the industry. Among the various renewable energy sources, the most popular is solar energy which can be easily installed. This type of renewable energy is more popular today. The performance of the solar energy system is affected by the availability of sunlight, the battery backup, and the load. Thus, the efficiency of the solar energy system depends on the above factors. It is very important that every solar energy system needs a charge controller to increase the efficiency of the total system. The solar charge controller has to control the charge stored in the battery backup, load, and switching concepts. A new model of the solar charge controller by the name smart switch is suggested which could improve the efficiency of solar energy by taking smart decisions in charging the battery backup, supplying the solar energy to the load when the battery is getting full, and then managing the energy storage in the battery backup, etc.*

Design/Methodology/Approach: *Developing a conceptual theoretical model by the name smart switch and studying the performance of the same by taking the values in different time intervals. Then analysis of the model is done using the ABCD framework.*

Findings/Results: *The performance of the model is studied by considering the values at various time intervals and the observations are noted in the tabular format. The values entered in the table are from the theoretical performance of the smart switch-a modified solar charge controller. From the table it is proved that the performance of the model is found to be optimal. The performance of the smart switch is analyzed using the ABCD framework.*

Originality/Value: *A new conceptual model is analyzed using ABCD framework by identifying the determinant issues and key attributes for each determinant issue. This analysis is proven to be adaptable in future technology.*

Paper Type: *Conceptual Research.*

Keywords: ABCD analysis framework, Solar energy, Solar charge controller, Technology, Environment, Determinant issues, Key attribute.

1. INTRODUCTION TO ABCD FRAMEWORK :

The ABCD analysis is developed for analyzing the product or service under the ABCD framework. The analysis has various determinant issues with key attributes. Each key attribute is analyzed using the constructs namely advantages, benefits, constraints and drawbacks [1-5]. Whenever there is a new product either proposed or produced has to be analyzed before and after it is introduced in the market. The analysis helps in understanding the product, its performance by taking various determinant issues and the key attributes for each determinant issue. This analysis helps the researcher to improve the product.

The purpose of ABCD framework is to identify the characteristics of the charge controller which is designed for the optimal utilization of solar energy. This chapter concentrates on the major issues pertaining to the performance of the charge controller based on the technology and then the business aspects during implementation. In this analysis, the determinant issues are identified and then the key attributes for each determinant issue are also identified [6]. The factors which are affecting the issues are discussed using the focus group discussion. Here the four identified constructs of ABCD

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 2

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

framework are considered namely advantages, benefits, constraints and disadvantages [7-12]. ABCD framework is a tool for the evaluation of the proposed model under various determinant issues. Each determinant issue has several key attributes and the model is evaluated on each key attribute of the particular determinant issue. For each key attribute of the determinant issue the advantage, benefits, constraints and disadvantages are identified. Finally, the model is evaluated in various angles for the manufactures, industry, marketing and finally the customers.

2. OBJECTIVES OF THE STUDY :

(1) To study and analyze the performance of the smart switch-a proposed model using ABCD framework.
(2) To determine the determinant issues which can be considered for analysis of the proposed model.
(3) To identify the various key attributes for each determinant issue.
(4) To apply each key attribute of each determinant issue to the proposed model and analyze the model with the ABCD constraints (Advantages, Benefits, Constraints, and Drawbacks).

3. THE METHODOLOGY :

The methodology includes the working of the proposed model and the analysis of the same. Then various determinant issues are identified. Later the key attributes are determined for every determinant issue. The ABCD analysis is done on every key attribute of the determinant issue. Here the determinant issues and the corresponding key attributes are chosen based on various parameters related to the proposed model considering the factors like technology, the contribution of the product to society, environmental benefits of the product, production, profitability, and the various stack holders of the proposed model.

4. THE ANALYSIS OF THE MODEL :

The block diagram of the model is shown in figure 1.
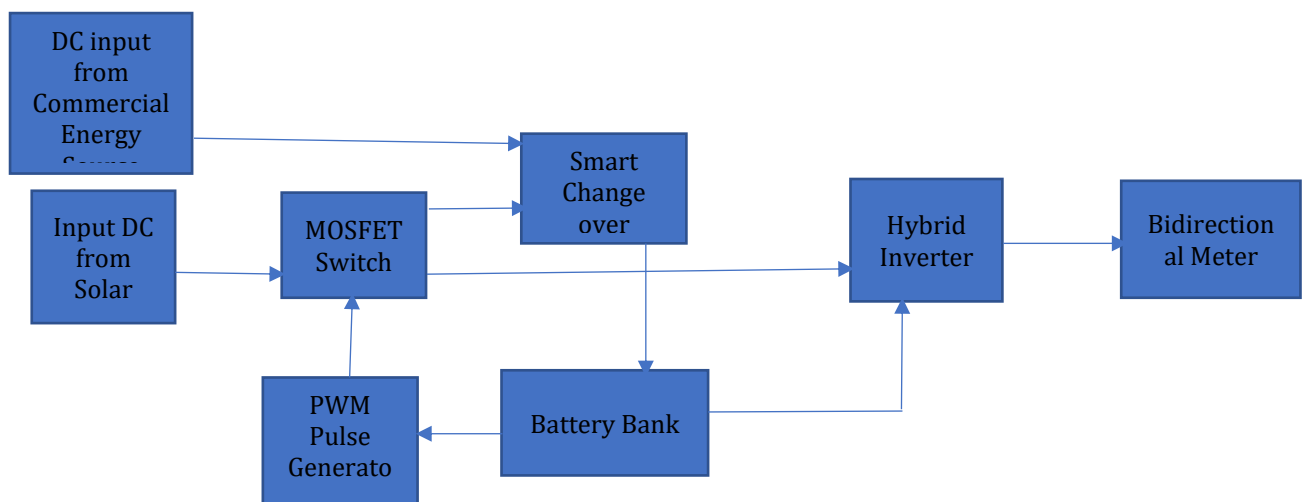
Fig. 1: The proposed Model

The model will demonstrate how efficiently solar energy is utilized for storing the energy in the battery backup as well as to supply the energy to the load when the battery is getting full. The analysis is done on a theoretical basis by studying the individual performance of the different stages of the model. The analysis of this model has three different tables analyzing the performance of the following features of the model:

- Working of the buck converter
- Working of the PWM solar charge converter
- Working of the smart switch

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 3

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

5. WORKING OF THE BUCK CONVERTER :

The buck converter is considered from the MPPT technology. Here only buck converter is considered because the performance of the solar PV system is such that the output voltage is more than the required voltage. Only during early morning and late evening, the PV output voltage is less than the required voltage. Thus, the boost converter is not considered. The buck converter reduces the output voltage of the solar PV system and increases the current. Thus, the power taken from the solar PV system increases with the buck converter [13-18].

The following table 1 shows the performance of the buck converter for solar panels which produces a maximum voltage of 18V and a current of 10A. The power rating of the solar panel is 120W. But the Panel can produce a peak power of 180W [19].

Table 1: Performance of the buck converter for a sample solar panel (18V 10A max)

S. No.	Time	Input Voltage	Input Current	Output V, C, P (without Buck Converter)	Output V, C, P (with buck converter)
1.	8.00 AM	5V	2A	NA	NA
2.	9.00 AM	10V	2A	NA	NA
3.	10.00 AM	18V	2A	14V, 2A, 28W	14V, 2.56A, 35.84W
4.	11.00 AM	18V	8A	14V, 8A, 112W	14V, 10.24A, 143.36W
5.	12.00 N	18V	8A	14V, 8A, 112W	14V, 10.24A, 143.36W
6.	1.00 PM	18V	8A	14V, 8A, 112W	14V, 10.24A, 143.36W
7.	2.00 PM	18V	6A	14V, 6A, 84W	14V, 7.68A, 107.52W
8.	3.00 PM	18V	4A	14V, 4A, 56W	14V, 5.12A, 71.68W
9.	4.00 PM	18V	2A	NA	NA
10.	5.00 PM	10V	2A	NA	NA

Table 2: Performance of the buck converter for a sample solar panel (36V 10A max)

S. No.	Time	Input Voltage	Input Current	Output V, C, P (without Buck Converter)	Output V, C, P (with buck converter)
1.	8.00 AM	20V	2A	NA	NA
2.	9.00 AM	24V	5A	24V, 5A, 120W	24V, 5 A, 120W
3.	10.00 AM	36V	7A	28V, 7A, 196W	28V, 8.96A, 250W

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 4

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

4.	11.00 AM	36V	8A	28V, 8A, 224W	28V, 10.24A, 286.72W
5.	12.00 N	36V	8A	28V, 8A, 224W	28V, 10.24A, 286.72W
6.	1.00 PM	36V	8A	28V, 8A, 224W	28V, 10.24A, 286.72W
7.	2.00 PM	36V	7A	28V, 7A, 196W	28V, 8.96A, 250W
8.	3.00 PM	24V	5A	24V, 5A, 120W	24V, 5 A, 120W
9.	4.00 PM	20V	2A	NA	NA
10.	5.00 PM	20V	1A	NA	NA

The output of the solar charge controller using conventional module for a panel of 12V 10A is
- The total power utilized without the buck converter is 504W
- The total power utilized with the buck converter is 645W
- The extra power production using buck converter is 141W

The output of the solar charge controller using conventional module for a panel of 24V 10A is
- The total power utilised without the buck converter is 1.3KW
- The total power utilised with the buck converter is 1.6KW
- The difference power utilization is 300W

The difference in power production is shown in table 2

Table 3: The difference in the power production with buck controller and without buck controller

S. No.	Panel Power Rate	Power Without using Buck Converter	Power with using Buck Converter	Difference in daily power production
1.	12V 10A	504W	645W	141W
2.	24V 10A	1.3KW	1.6KW	300W

This difference observed is for a single panel. Normally in the house in order to get more power series of panels are installed. In such condition the power generation difference factor will be multiplied by the number of panels.

6. WORKING OF THE PWM SOLAR CHARGE CONVERTER :

The output power of the solar PV module is converted and increased as per the requirement of the battery backup as well as the load by the buck converter. The next stage is the PWM solar charge controller which controls the charging of the battery backup as per the need of the battery backup [20-23]. Simultaneously the solar power generated is delivered to the load through the inverter. The charging of the battery backup as well as delivery to the load is controlled by the duty cycle. The duty cycle varies with the sample voltage from the battery backup. The working of the PWM solar charge controller is shown in the figure 2.
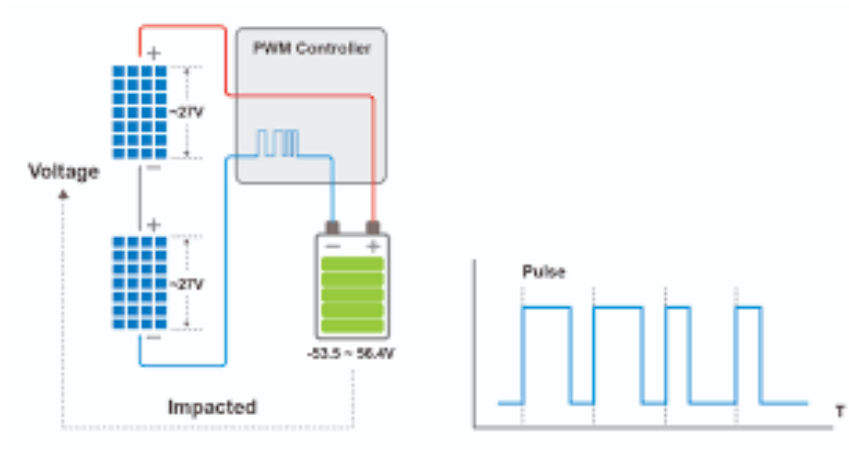
P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 5

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

Fig. 2: The variable pulse generation from the PWM Oscillator.

The different possibilities of the duty cycle of the PWM output is shown in figure 3.

Output Waveform of the PWM Oscillator during Low Battery power

Output Waveform of the PWM Oscillator during 50% battery charged

Output Waveform of the PWM Oscillator during battery fully charged.
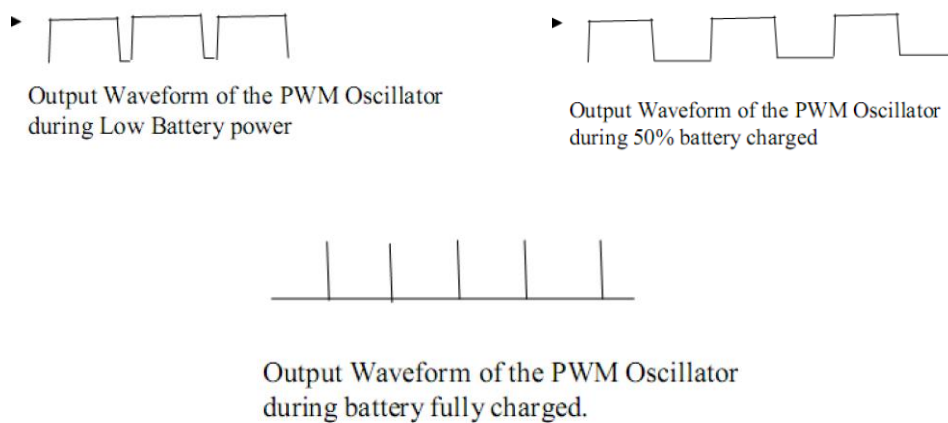
Fig. 3: The sample output of the PWM oscillator during different stages of the battery Power

The power wastage in the current PWM solar charge controller is explained in table 4.

Table 4: Working of the PWM solar charge controller. (Considering the Power output of a solar panel is 150W for a 12 V Battery)

S. No.	Duty cycle	Power Storage in Battery Backup	Power Waste
1.	100%	150W	NIL
2.	90%	135W	15W
3.	80%	120W	30W
4.	70%	105W	45W

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 6

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

5.	60%	90W	60W
6.	50%	75W	75W
7.	40%	60W	90W
8.	30%	45W	105W
9.	20%	30W	120W
10.	10%	15W	135W
11.	0%	0W	150W

The performance of the proposed PWM solar charge controller is shown in table 4.

Table 5: The PWM solar charge controller of the proposed model.

S. No.	Battery Voltage	PWM duty cycle	Remark
1.	12.6+	0%	No charging
2.	12.5	10%	90% wastage
3.	12.42	20%	80% wastage
4.	12.32	30%	70% wastage
5.	12.20	40%	60% wastage
6.	12.06	50%	50% wastage
7.	11.90	60%	40% wastage
8.	11.75	70%	30% wastage
9.	11.58	80%	20% wastage

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 7

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

10.	11.31	90%	10% wastage
11.	10.5 and below	100%	No wastage

For a battery of 12V the different voltages with the percentage of charging is shown in table 5.

Table 6: The different stages of battery charging from the PWM charge controller [24-26]

Voltage	State of Charge
12.6+	100%
12.5	90%
12.42	80%
12.32	70%
12.20	60%
12.06	50%
11.9	40%
11.75	30%
11.58	20%
11.31	10%
10.5	0%

From the above table it is observed that battery voltage from 10.5V to 11.31V is considered to be critical, battery voltage from 11.58V to 11.75V is considered to be minimum and above 11.90V is considered to be fair. The battery voltage 12.06V is considered to be 50% and any voltage above 12.6+ is considered to be 100%. Normally the battery stops charging when the voltage of the battery reaches 14V.

7. WORKING OF THE SMART SWITCH :

The smart switch of the proposed model plays an important role in optimally utilizing the solar energy to charge the battery backup as well as the supplying the energy to the load. Currently the solar charge controller prefers the solar energy from the available energy sources during day time when the solar energy is available. But during night time when there is no availability of the solar energy the charge controller uses the commercial energy for charging the battery backup. Bu the new model uses the following algorithm to switch between the conventional energy source and the solar energy as shown in the table 7.

Table 7: The switching algorithm of the smart switch

S. No	Battery Voltage	Input mode
1.	10.5	1. Solar 2. Conventional Source
2.	11.75	1. Solar 2. Conventional Source
3.	12.06	1. Solar
4.	12.5	1. Solar

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 8

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

The performance of the smart switch utilizes solar energy to the maximum extent. Here solar energy is used for charging whenever the battery bank needs the energy to be stored. This reduces the usage of conventional energy for charging the battery backup during night.

8. ABCD ANALAYSIS FRAMEWORK AND SYSTEMATIC REVIEW OF ITS USAGE :

The ABCD analysis framework is used for the analysis of the individual characteristics, effectiveness of the new idea during the final implementation, characteristic of the system, the effectiveness of the strategy used in developing the model and its business value [27]. There are various strategies for studying the individual characteristics, various strategies to e applied in a given environment using PEST analysis, SWOC and SWOT Analysis, McKInsey 7s framework, five force model of Portal, ICDT Model, etc. ABCD model is the recently introduced model more suitable for analysis of business systems, business concepts, technology, various business ideas implementing those new technologies. In this model either the new innovative model or the impact of the new technology in the business area or the impact of the new technology in production and sales and service are analyzed using various determinant issues. Here every determinant issue is analyzed under four constructs namely advantages, benefits, constraints and disadvantages [28]. The ABCD analysis can also be extended to analyze the material, human resource, machine, technology to be adopted, market opportunities etc. ABCD analysis can also be qualitative or quantitative [29]. In qualitative analysis either the concept, the system, the strategy used and the technology adopted are considered. In quantitative analysis the weightage to each critical element under each construct are considered.

Here the smart switch is analyzed under three types. They are

- The impact of the product for the external environmental effects
- The study of the new product/service
- The company strategy in handling the product from production till marketing.

In the case of the impact of the product for the study on external environmental effects, the ABCD analysis framework concentrates on the analysis of the smart switch by considering renewable energy and environmental pollution as the key attributes for the study. As the smart switch is contributing innovative idea in designing the optimized solar charge controller, the device is contributing towards the renewable energy system. The main objective of the renewable energy system is to improve the efficiency of the system. Another key attribute is environmental pollution. The ABCD framework analyses and explains how the new product improves the environmental pollution [30].

The study of the new product and service of the same is another type of analysis of the smart switch under ABCD frame. Here the key attributes which are considered are the challenges faced by the industries to get the market for the smart switch. Since the smart switch is a theoretical research outcome, the production industries have to use their own technological idea for the implementation. The idea must concentrate on the cost, efficiency and service after production. The ABCD framework concentrates on the above concepts.

The company must design a strategy in production, marketing and performance of the product, service to the same after sales. As the smart switch is a theoretical concept, the company has to face several challenges in handling the product from manufacturing till marketing. The company has to set up the strategies for the services after the sales. The company must develop the working model by considering the various units of the smart switch. The performance of the final product has to be tested before it is introduced in the market. The company has several challenges in implementation like technology, cost, performance and after sales service. These points are analyzed using ABCD framework [31].

Following table 8 lists the various area of the ABCD analysis with focus area with the reference

Table 8: Review of ABCD Listing

S. No.	ABCD Listing Area	Focus	Reference
1.	Company Analysis	Study on various activities of the Company including the production, role of IT, future plans, disaster management	Aithal, P. S. (2017). [1]
2.	Business Case Studies	Business cases of Companies, Issues related to individual companies,	Aithal, P. S. (2017). [2]

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 9

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

		Difference Between Research Case Study & Teaching Case Study	
3.	Industrial Analysis	Business Management, Business Research, Industrial sectors, Industry trend Analysis, Environmental analysis, Competitor Analysis, Alternative Product/Service Analysis etc.	Aithal, P. S. (2017). [3]
4.	Company Case Studies	Production, marketing, Service, Financial and all the areas which are essential to the company.	Aithal, P. S. (2017). [4]
5.	Factors & elemental analysis of six thinking Hats technique using ABCD framework	Consideration, attitude and action on various colors of Hats, basics of the various colors, way of thinking for different colors, ABCD Analysis of six thinking Hats.	Aithal, P. S., Kumar, P. M., & Shailashree, V. (2016). [5]
6.	Annual Research Publicity using ABCD Framework	ABCD analysis for the stake holders who are into publications	Aithal, P. S., VT, S., & Kumar, P. M. (2016). [6]
7.	Private University System	High levels of intellectual abilities, Establishment of various facilities for Education, Research and Development, Public consultancy, National and International collaborations, New model of education.	Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). [7]
8.	Business	Business models, Strategies, Operations Concepts, Operations Ideas, Effecting factors, Constituent Critical Elements	Aithal, P. S. (2016). [8]
9.	Organizational Performance	Theory A implementation on Organization. Essential elements of Theory A, Four steps of each stage, Organizational Assumptions.	Aithal, P. S., & Kumar, P. M. (2016). [9]
10.	Placement in Higher Education system	IEDRA model of placement, various Determinant issues and Key attributes for the student.	Shenoy, V., & Aithal, P. S. (2017). [10]
11.	Organic food product	Purchase intention of organic food product, impact of ABCD analysis on purchase intention, effecting factors on stack holders	Mendon, S., & Aithal, P. S. (2022). [11]
12.	Online food delivery services	Analysis of online food delivery system, Sustainability, Structure of ABCD framework	Frederick, D. P., Sujaya, H., & Salins, M. (2022). [12]
13.	Health Care Professionals	Task shifting, Optimum health Solution, Job opportunity, Alternative healthcare workers, Long term treatment.	Aithal, A., & Aithal, P. S. (2017). [32]
14.	Aviation Industry	Cabin crew, Strategies and factors of stress induction, measures, interpersonal stress,	Kumari, P., & Aithal, P. S. (2022). [33]
15.	International Business and its environment	International Business Decisions, SWOK Framework, International Business Strategies	Aithal, P. S. (2017). [34]
16.	Higher Education institutions	Corporate Sustainability, choice-based education system, smart library, Student performance, learning outcome	Nayak, P., & Kayarkatte, N. (2022). [35]

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 10

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

17.	Analysis of NAAC Accreditation.	Faculty performance, Student Support, social, environment, community Engagement, Infrastructure, Research	Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). [36]
18.	Higher Education	Stage Model, Academic Issues, Student issues, Administration issues, various stack holders.	Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). [37]
20.	Black Ocean Strategy	Market space, Business issues, various issues related to the Business and market.	Aithal, P. S., Shailashree, V., & Kumar, P. M. (2015). [38]
21.	Business Models and Concepts	Organizational issues, Operational issues, Technological issues, Employers and employees, Customers, Social and environmental issues	Aithal, P. S., et.al. (2015). [39]
22.	Temperature-Dependent Parameters for Cold Regions	headwater catchment of the Golmud River, TERRACLIMATE, Cold Region,	Wang, X., Gao, B., & Wang, X. (2020). [40]
23.	BoP Market	Practices of Indigenous Management, mutual values, marketing of BoP, Digitization.	Raj, K., & Aithal, P. S. (2022). [41]
24.	Cleaning the environment with the help of nanotechnology	Various pollutants, different methods of cleaning, scale of cleaning using nanotechnology filters	Aithal, S., & Aithal, P. S. (2020). [42]
25.	Mega Machine Design using Nano Technology	Air pollution, toxic materials, biomass fuel, uses of various nano materials, various filters	Aithal, S., & Aithal, P. S. (2020). [43]
26.	New Research Indices	Various indices, Effecting factors, various stake holders of the research	Aithal, P. S., & Aithal, S. (2017) [44]
27.	Comparative study on the quality of research publications with respect to the research indices.	Various research indices,	Aithal, P. S. (2017). [45]
28.	System and Technology analysis	Structure of ABCD framework, various issues, constituent critical elements	Aithal, P. S. (2021). [46]
29.	Analysis of Mangalore International Airport	Growth analysis and fact analysis of the Airport, Aviation Industry, Public private partnership.	Kumari, P., & Aithal, P. S. (2020). [47]
30.	Smart Library Model	Digital library, files in audio, video and text, Universal Resource Center.	Aithal, P. S. (2016). [48]
31	Green Energy	Global warming, Solar energy, Industrial contribution to global warming.	Aithal, P. S., & Acharya, S. (2016). [49]
32	National Institutional Ranking System	Teaching learning resources, Research productivity, outcome, outreach, perception.	Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). [50]
33	Nano Technology as a green technology	Factors and elemental analysis, Universal Technologies.	Aithal, P. S., & Aithal, S. (2018). [51]
34	Environmental and Ecological Management	Role of ICCT technology, Environmental management, Ecological Management.	Aithal, P. S., & Aithal, S. (2022). [52]

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 11

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

35	New Directions for the Scholarly Research	Innovative research methods, research models, out of box thinking.	Aithal, P. S., & Aithal, S. (2019). [53]
36	Electricity from Microbial cells	Waste water management, bacterial analysis, analysis of MFCs.	Acharya, S., & Aithal, P. S. (2017). [54]
37	Use of Green Education concepts in Higher Education	Adoption of technology in Education, Sustainable Education.	Aithal, P. S., & Rao, P. (2016). [55]
38	Nano Technology as a Green Technology	Clean, Secure, low cost technology, various issues like organizational, Employee, customer, environmental etc.	Aithal, P. S., & Aithal, S. (2018). [56]
39	Student Development Model and Service Model	Srinivas University, Integration between student and service development models	Aithal, P. S., & Maiya, A. K. (2022). [57]
40	Various theories in Organizational Behavior	Theory X, Theory Y, Theory Z and Theory of Accountability	Aithal, P. S., & Kumar, P. M. (2016). [58]
41	Innovations in B. Tech. curriculum.	Use of STEAM model, ESEP model and IPR features in curriculum.	Aithal, P. S., & Aithal, S. (2019) [59]
42	Use of AB Theory in Organizational Leadership	Various Leadership theories, Types of leadership theory, model of attitude behavior	Aithal, P. S., & Aithal, S. (2019) [60]
43	Student grading in Higher Education system	Competency based education, performance-based student outcome, choice based credit system	Aithal, P. S., & Kumar, P. M. (2019, October) [61]
44	Mobile Information Communication Technology	Secured Mobile Services, Constant changes in Mobile Technology, Functions and Features of 5G	Aithal, P. S. (2016) [62]
45	Nano Technology in Renewable energy Sectors	Business opportunity of nano technology in energy sector.	Aithal, P. S., & Aithal, S. (2016) [63]
46	Multifactor Authentication of fingerprint Hash Code.	Password, OTP, Fingerprint hash code	Aithal, P. S. (2018) [64]
47	A Case Study on Institutional Values and Social Responsibilities	A Case Study with respect to Srinivas University.	Aithal, P. S. (2022) [65]
48	Water purification system Ideal vs Practical	Conceptual Application of nanotechnology for water purification system.	Aithal, S., & Aithal, P. S. (2018) [66]
49	Online E Campus based Recruitment	Recruitment for Berger Paints.	Shenoy, V., Aithal, P. S., & Pai, R. (2018) [67]
50	Online education system	Impact of it in higher education system	Aithal, P. S., & Aithal, S. (2016) [68]
51	Ideal Education System	Realization of the system in the current environment	Aithal, P. S. (2021) [69]
52	Corporate Social Responsibility with respect to the Bank	Indian Public and Private Sector Banks	Aithal, P. S. (2021) [70]
53	Online E Campus Interview Training	Using MOOC framework especially for Graduates	Shenoy, V., Acharya, S., & Aithal, P. S. (2018) [71]
54	Business Excellence with the help of	Improvement of the organizational business excellence	Aithal, P. S. (2021) [72]

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 12

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

	Theory of Accountability		
55	Generating the wealth near the base of the pyramid	Generation of revenue, wealth creation	Raj, K., & Aithal, P. S. (2018) [73]
56	Organizational problem solving using six thinking hats	Decision making, Managerial Problem Solving	Aithal, P. S., & Kumar, P. M. (2016) [74]
57	Curriculum design for Business and IT fields	Student centric design and Implementation	Aithal, S. (2016) [75]
58	Photonic Applications	Dye-Dopped Polymers	Aithal, S., & Aithal, P. S. (2016) [76]
59	Ideal Software and its Realization	Ideal Software Characteristics	Aithal, P. S., & Pai T, V. (2016) [77]
60	New Research Indices	Annual Research Publication Index	Aithal, P. S. (2017). [29]

Table 9: Review of factors and elemental ABCD analysis with Determinant Issues

S. No.	ABCD Listing Area	Focus	Reference
1	Higher Education	Choice based credit system	Aithal, P. S., & Kumar, P. M. (2016). [78]
2	E-Business	Work from Home	Reshma, Aithal, P. S. et al (2016). [79]
3	Financial activities of Nepal	Green Financing	Mishra, K., & Aithal, P. S. (2022). [80]
4	Engineering Industries	Industry 4.0 standard	Sony, M., & Aithal, P. S. (2020) [81]
5	IBM Blockchain Service	A case study on blockchain service	Bhuvana, R., & Aithal, P. S. (2020). [82]
6	Student centric learning	Method of learning through planned hard work	Aithal, S., & Aithal, P. S. (2016). [83]
7	Indian Engineering Industries	Industry 4.0 readiness mode	Sony, M., & Aithal, P. S. (2020). [84]
8	Food Industries (Restaurants)	Food waste- A Consumer intention	Salins, M., & Aithal, P. S. (2022). [85]
9	Comparative Analysis for managing the people and the performance	Theory X, Theory Y, Theory Z and Theory A	Aithal, P. S., & Kumar, P. M. (2016). [86]
10	Higher Education Institution	Learning outcomes and the performance of the students.	Aithal, P. S., & Kumar, P. M. (2016). [87]
11	Product and Services	Nano technology	Aithal, P. S., & Aithal, S. (2016). [88]
12	Authentication	Fingerprint, Hash code, Password and OTP related multi-functional	Prasad, K., & Aithal, P. S. (2018). [89]
13	Education system	Teacher quality	Aithal, P. S., & Kumar, P. M. (2016). [90]
14	Srinivas Institute of Management Studies	Automated administrative system	Reshma, P et al (2015). [91]
15	Education system	Teaching and learning process	Aithal, P. S., & Kumar, P. M. (2016). [92]
16	Education system	Risk decisions by using six thinking hats	Rangi, P. K., & Aithal, P. S. (2020). [93]

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 13

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

17	Higher Education	Student evaluation system and reforms	Aithal, P. S., & Kumar, P. M. (2016). [94]
18	Indian Equities and Machine learning	Risk determination A case study	Rangi, P. K., & Aithal, P. S. (2021). [95]
19	Research centers	Small atomic research centers	Aithal, P. S. et al (2022). [96]
20	Organizational decisions	Alternative or parallel strategies to be followed	Aithal, P. S., & Aithal, A. (2018). [97]
21	Indian Universities and academic institutions	Block chain technology, Reputational risk	Rangi, P. K., & Aithal, P. S. (2020). [98]
22	Higher Education	Choice based credit system	Aithal, P. S. et al (2016). [99]
23	SME, MSE and SMSE	Role of MUDRA	Aithal, P. S., & Sharma, K. R. S. (2022). [100]
24	Retailers in India	Organizing the unorganized Retailers	HR, G., & Aithal, P. S. (2020). [101]
25	Higher Education	Student enrolment and retaining the diversity.	Aithal, P. S., & Kumar, P. M. (2016). [102]
26	Library Management	IT innovations in Library	Harischandra, P. et al (2016). [103]
27	Corporate Auditing	B Com syllabus	Aithal, P. S., & Noronha, S. (2016). [104]
28	Indian top business school	Research performance	Aithal, P. S. (2016). [105]
29	Managerial decision making	Lateral thinking	Aithal, P. S., & Kumar, P. M. (2017). [106]
30	MBA program	Comparative study between Private and Public Universities	Aithal, P. S. (2015). [107]

Table 10: Review of factors and elemental ABCD analysis with Determinant Issues

S. No.	ABCD Listing Area	Focus	Reference
1	Indian Business Schools	Research and Publications	Aithal, P. S. (2016). [108]
2	Technology and system	ICCT and nano technology	Aithal, P. S. (2021). [109]
3	Private Banking Jobs	Entry level competency	Shenoy, V., & Aithal, P. S. (2020). [110]
4	Higher Education System	MCA degree of Srinivas University	Aithal, P. S., & Pinto, J. (2016). [111]
5	Nano Technology	Commercial Products	Aithal, P. S., & Aithal, S. (2016). [112]
6	IT industry	Recent trends in IT	Lathika, K. (2016). [113]
7	Higher Education system	Individual Research and publication	Aithal, P. S. (2016). [114]
8	Indian Business	Green Business	Mendon, S., Salins, M., & Aithal, P. S. (2019). [115]

9. THE DETERMINANT ISSUES AND THE KEY ATTRIBUTES :

The determinant issues are those issues which directly deal with the model either in connection with the production, marketing, maintenance and service and consumer behavior, etc. Each determinant

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 14

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

issue has its own set of key attributes which support the corresponding determinant issue. Later the four identified constructs namely advantages, benefits, constraints and disadvantages of each key attribute is identified. For the proposed model the determinant issues and the key attributes are shown in the following table 11.

Table 11: Determinant issues and the key attributes for each determinant issues

S. No.	Determinant Issues	Key Attributes
1.	Technology	1. Product Innovation 2. Product Quality 3. Product Features 4. Demand
2.	Environmental Sustainability.	1. Renewable energy 2. Pollution Control
3.	Profitability	1. Product Innovation 2. Pricing 3. Efficiency
4.	Product/Service	1. Demand in the Market 2. New Product 3. Service
5.	Stack Holders	1. Industry 2. Customer 3. Government 4. Society 5. Service Providers

The determinant issues are identified by considering the various parameters where the new model is going to bring the changes while considering the currently available models. Technology is taken as the first determinant issue as the model discusses with the implementation of the new technology by studying the current technology. Here various challenges are to be considered to explain the new technology and various constructs on the various key attributes for the given determinant issue are discussed. The key factors will explain the determinant issue in various dimensions where the attributes for each key factor give the explanation of the corresponding determinant issue under the corresponding key factor.

For the proposed model which is analyzed in the previous chapter has identified five different determinant issues in the domains where the model is going to bring the changes. The five determinant issues are listed in table 11. The first determinant issue is the technology issue which highlights on the implementation of the new technology by modifying the current technology on the proposed model. Here the key attributes including the impact of the innovation on the model is considered. The quality of the new model by implementing the new technology is then discussed. The features of the new model are then discussed and what would be the future market demand for the new product is then discussed for the different key attributes.

The different key attributes under this determinant issue are Product Innovation, Product Quality, Product Features, Demand. Here the key attributes are identified based on the new model suggested which is performing better than the currently available models. The various attributes on the innovation of the product, quality of the product, the various features of the product and what would be the future demand for this product are considered. The following table lists out the various constructs for the determinant issue as the technology with four key attributes.

10. THE ABCD ANALYSIS :

The ABCD analysis of the key attributes under each determinant issue is shown in table 12 to table 16 below.

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 15

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

Table 12: The constructs for four key attributes under Technology

S. No.	Key Attribute	Advantage	Benefit	Constraint	Drawback
1.	Product innovation	Blended technology which uses both Buck conversion and PWM in an effective manner	The entire solar energy from the PV module will be effectively utilized.	Managing both load as well as the battery bank together.	Integration of different technologies namely Buck conversion, PWM, Load balancing, smart Switch.
2.	Product Quality	Improved efficiency	Optimum utilization of the solar energy	Impedance balancing to the quality	Difficult to find out the quality of the individual units of the model and the combined effect of the same with respect to the quality
3.	Product Features	Auto selection of the load/battery for charging. Use of PWM technique for charging. Trickle charging. User defined charging mode selection	Balancing of battery backup and the load. Optimum utilization of Solar energy. Part of MPPT technology used in this model.	Delivering energy to load while battery backup is full Design of the integrated inverter system that could prefer solar energy as well as the conventional energy.	Integrated load balancing system. Switching circuit algorithm for selection of battery voltage.
4.	Demand	Expecting a good market due to the various features of this model. More energy production and utilization attracts a good market. Thus, the market demand increases.	Higher efficiency. More energy production from Solar PV model. Load balancing.	Bringing awareness in the market about the new model. Use of renewable energy and its advantage. Customers always look into the short-term economic benefits from the model.	Getting manufacturers for the proposed model. Bringing the market awareness. After sales service.

Table 13: The constructs two four key attributes under Environmental Sustainability.

S. No	Key Attribute	Advantage	Benefit	Constraint	Drawback
1.	Renewable Energy	Eco friendly. Minimum maintenance cost. No power outages.	One time investment. No rental and other hidden charges.	Bringing awareness among the people. People need shot term benefits	Initial investment may be huge. Permission from the concerned Authorities when

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 16

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

			Support from the Government.	instead of long-term benefits. Minimum maintenance from the customer is not possible. Energy production varies with season.	it is grid connected. Long term return policy.
2.	Pollution Control	No Carbon emission. Pure air. Friendly to the greenery.	Good health. Clean energy.	Contribution on pollution control is very less. Awareness on this aspect is very poor.	Dependency on solar energy without depending on traditional energy is costly and people don't think of switching over this technology even after knowing awareness of the solar energy system and its contribution to the pollution control.

Table 14: The constructs for three key attributes under Profitability

S. No.	Key Attribute	Advantage	Benefit	Constraint	Drawback
1.	Product innovation	Optimum energy utilization. Integration of the best technologies of the existing charge controllers. Better performance is expected.	No need to increase the energy from solar PV system than required as the efficiency is better than the existing charge controllers.	Adopting this technology in the production section as the cost is higher than the current technology.	Complicated design may be a reason for the production. Service issues after sales.
2.	Pricing	Higher pricing is possible due to the improved technology	Long term financial benefits.	Customers need short term recovery which may not be possible. Difficult to grab the market due to higher price.	Marketing is challenging.
3.	Efficiency	Higher efficiency	Maximum utilization of the solar energy.	Efficiency increases with proper load and battery bank. This condition is difficult sometimes.	Finding out the efficiency in all condition is the drawback as the solar energy seasonal which changes from time to time.

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 17

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

Table 15: The constructs for three key attributes under Product/Service

S. No	Key Attribute	Advantage	Benefit	Constraint	Drawback
1.	Demand in the Market	After proper knowledge we can expect a good market.	Satisfied customers after using this technology	Educating the market about the benefits of the proposed model. Initial market capturing.	Awareness is less. Market still is not accepted any kind of renewable energy and green energy. Government policy to implement the green energy is a drawback.
2.	New Product	Efficient output. Optimum energy usage.	Less investment on Solar PV system. Maximum solar power utilization	Social awareness	Knowledge about the service issues. Proper service in case of fault.
3.	Service	Easier service. Computer aided servicing technology helps in fault identification.	Fast service. Quick fault identification and service.	Knowledge about the technology and fault identification.	Service centers at different locations. Upgradation in the service to accommodate

Table 16: The constructs for five key attributes under Stack holders

S. No.	Key Attribute	Advantage	Benefit	Constraint	Drawback
1.	Industry	More business if market accepts	Production, sales, customers and after sales service will be benefitted from the technology.	Initial investment needs good market. But the current market is not oriented to the green energy.	Market ignorance on Green technology. Weak government policy to encourage such technology.
2.	Customer	Better results. Satisfaction after implementation.	Customer Satisfaction.	Customer awareness towards the new technology.	Afraid to learn and implement the new technology.
3.	Government	Pollution Control. Encouraged green technology	More profits. Good health.	Customer awareness. Government policies. Interests among the official.	Implementation of the new technology. Government policy makers. Facility in all the places.

P. Sridhara Acharya, et al. (2023); www.srinivaspublication.com

PAGE 18

International Journal of Applied Engineering and Management Letters (IJAEML), ISSN: 2581-7000, Vol. 7, No. 2, April 2023

SRINIVAS PUBLICATION

4.	Society	Clean energy. Self-dependency. Less Pollution. Less contribution to carbon emission.	Improved life style. Lean environment. Free to select the energy.	Changing environmental condition. Awareness about the technology. Short term return requirement.	Difficult to educate the society.
5.	Service Providers	New technology to be implemented	More outcome in the technology. New Technology	Less in numbers. Lack of knowledge about the technology.	Implementation count is less due to lack of awareness among the society.

11. CONCLUSION :

By referring to the above tables it is observed that the framework of ABCD analysis can be used to analyze the new model in different dimensions by taking various determinant issues which are belonging to different dimensions. The model is then analyzed using various key attributes for each determinant issues. Thus the model is tested in more specific key attributes and for every key attribute the model is analyzed using ABCD constraints wherein the advantages, benefits, constraints, and drawbacks of the model for each key attribute of a specific determinant issues is analyzed. The proposed model is analyzed under five different determinant issues and the above table has given the various constructs for each key attribute. Overall, it is observed that the new model has a lot of benefits over the current technology which is implemented. But to implement the new model a lot of challenges have to be faced in making the society understand the same. Also, the various government policies may be some constraints for the new model.

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PAGE 19

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PAGE 21

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PAGE 26