Design and Accuracy Assessment of a Multi-Input Single Ended Primary Inductor Converter (SEPIC) for Highly Efficient Output from Hybrid Sources of Renewable Energy

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Abstract—**Solar energy has long been considered the lowest-cost energy option all across the world. Due to various environmental factors, the PV Module is not self-sufficient in harvesting the maximum amount of solar energy. This is where our proposed topology stands out. In this paper, a hybrid topology of an off-grid energy-harvesting system (integrating Solar Photovoltaic (PV) Module with Bicycle Dynamo Generator) adopting a DC-DC multi-input-single-output (MISO) Single Ended Primary Inductor Converter (SEPIC) for isolated islands has been proposed. For boost mode operation, we constructed a conventional SEPIC-based SISO converter circuit and compared its performance to our suggested hybrid architecture of the SEPIC-based MISO converter system. The prototype of the suggested hybrid system was created following an optimal design technique for small-scale performance analysis. Our proposed MISO SEPIC circuit is intended to function at a practical input voltage of 12.1 V DC and provides an estimated output voltage of 53 V DC at the load side, with a 10W output power. To get the maximum voltage at the output end, the operating duty cycle for the proposed converter circuit is recorded as 81.49% with a gain of 4.4. From the hardware analysis and field-test data, we determine a 91.6% efficiency rate for the suggested prototype. A comprehensive and detailed investigation of the suggested topology has been carried out through software simulation using MATLAB/Simulink. While performing both the hardware and software analysis, different intermittence conditions, solar irradiance, and seasonal variance were also taken into account.**

Keywords—Solar Panels, Hybrid Multi-Port Converter, Topology, Voltage Optimization, SEPIC.

I. INTRODUCTION

Climate change, rising oil costs, global warming, and the scarcity of fossil fuels have heightened interests in renewable energy resources like Solar Photovoltaic (PV) panels and electrical power generation via bicycle pedals. Smart and effective usage of renewable energy sources is gaining popularity and earning peoples' trust due to its strong position in environmental protection. Renewable energy projects can help rural communities get out of poverty trap if they are feasible and well implemented. Bangladesh is extremely vulnerable to climate change due to its topography. According to the Global Climate Risk Index (CRI), it is one of the ninth most vulnerable countries in the world [1]. On the other spectrum, the opportunity to build green infrastructure from the ground up is the biggest challenge here. This is where renewable energy sources might be a realistic solution to Bangladesh's energy issue. Solar energy has endless possibilities for power optimization in large quantities all around the globe. It has the potential to substantially decrease the energy bills of local poor families while also making a major contribution to the reduction of greenhouse gas emissions. Bangladesh's government has taken significant steps to assist this industry flourish and has had a substantial influence on millions of people, particularly in rural regions. These initiatives have alleviated the total demand for electricity from the national grid creating opportunities for hundreds of thousands of people in the job sector. As of 2021, the online archive of SREDA shows that the off-grid installation of solar power is nearly 346.19 MW. Whereas, the on-grid installation of solar power is nearly 136.6 MW. The total combined installation of solar power all over the country is 482.79 MW [2]. Most power generators produce low voltage, but, require high-gain converters to meet load demands. The development of high static gain DC-DC converters is crucial owing to the growing demand for this Power Electronic technology in a variety of low DC voltage applications [3]. A multi-input converter (MIC) is required to develop a multi-source technology that increases the typical DC-DC converters' efficiency ten-fold [4]. Our developed multi-input DC-DC converter is a simple device that can be loaded with many input sources. This paper proposes a modular, non-isolated converter that can handle varied input sources and output loads derived from a simple SEPIC structure. The SEPIC converter was given special consideration due to its unique qualities such as enhanced power factor from continuous input current, non-inverting output, gracious reaction, and true shutdown during short circuits [4]. A converter circuit prototype was created to investigate the SEPIC circuit's boost mode. The input current characteristic of these converters, on the other hand, is a serious issue [5]. Another challenge for these DC-DC converters is that they must withstand the nature of their input current. By raising the input current to a certain level, a DC-DC converter with a stable input current increases the system's dynamic performance. Aside from the PV Module, we have proposed integrating a bicycle dynamo as the second renewable energy source in this hybrid topology. In rural areas, bicycles are the primary mode of transportation for locals. When pedaling a bicycle, humans are capable of generating about 150W of power [6]. A bicycle dynamo can convert the mechanical energy generated by people pedaling their bicycles into electrical energy. This is particularly useful in our rural regions where the majority of people rely on bicycles for transportation. We all know that the energy produced by a single renewable source is insufficient to satisfy the demand for electricity for a particular rural family in distant islands. In this case, the novel solution of combining various renewable energy sources via DC-DC power converter can be a go-to option for these families. Several feasibility studies of rural electrification using renewable technology have already been carried out focusing on the distant islands of Bangladesh [7]-[10]. Combining PV Modules with other renewable energy sources makes more sense financially (e.g. generating electrical power using bicycle pedaling for this project). The multiport converter is an efficient approach to ensure the optimum power harvesting from multiple renewable energy sources.

II. Literature Review

Before we get into the essentials of the design, let's have a look at the SEPIC-based MISO architecture. We explored and read several studies focusing on the hybrid renewable energy application, multi-port DC-DC SEPIC converter circuit and SEPIC converter efficiency. Rehman et al. [11] have presented novel topologies and identified new power conversion characteristics. Multi-input-multi-output DC–DC converters have successfully replaced SISO converters. No single architecture can achieve the objectives of affordability, reliability, flexibility, efficiency, and modularity, according to research on several multi-input DC–DC converter topologies. Apart from that, Moradpour et al. [5] have proposed a novel boost DC-DC converter structure. The suggested converter has a high voltage conversion gain as well as greater efficiency, which are both beneficial. Anuradha et al. [4] have also proposed an efficient method of synthesizing a three port non-isolated converter from a Single Ended Primary Inductor Converter (SEPIC). The main SEPIC converter has two cells: source and load. A three-port SEPIC converter is made up of two source cells linked by DC link capacitors to a common load cell. Mohanty's experiment [12] has presented a multi-input DC-DC SEPIC. Although the output voltage has positive polarity, it may or may not be equal to the input voltage. It operates as a buck, boost, or buck-boost converter, which means it can either step up or step down the voltage. A series capacitor is required to link energy from the input to the converter's output since the polarity of the output voltage cannot be changed. Sangalad et al [13] have developed and analyzed a dual input SEPIC converter. This method generates gating pulses for switching devices. This system is more versatile because it takes a wide range of input sources. Using a dual input SEPIC instead of two single input converters saves money and reduces losses. For renewable energy applications, the number of inputs may be extended for any n' values. Niguchi et al. [14] have proposed a method to calculate the power production performance of a bicycle hub dynamo. The output power of the hub dynamo is minimal, making 3-D finite element analysis difficult to predict. First, the hub dynamo's output voltage is calculated with magnetic hysteresis and poor magnetization. Then, the output voltage is tested on a genuine hub dynamo. Amritanand and et al. [15] have suggested a novel way to store energy generated by cycling and utilize it to light up rural dwellings. A Solar Panel is also part of their arrangement, which provides power even when the bicycle is not in use and is left outside all day.

III. Overview and Working Principle of the Proposed System

Fig. 1. depicts a simplified visual representation of the proposed topology, based on [4]. Our hybrid topology is a Single Ended Primary Inductor Converter (SEPIC) based multi-input-single-output (MISO) converter for photovoltaic (PV) based bicycle dynamo system. The proposed system

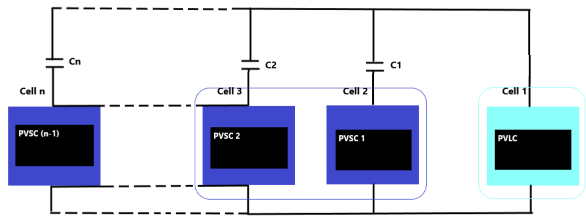

Fig. 1. Generalized Diagram of n-port SEPIC converter

configuration shows that the number of ports may be increased or lowered even further by connecting or detaching the extra pulsating voltage cells (PVC), depending on the availability of the power and data input sources. In this paper, we have proposed a unidirectional SEPIC-based MISO converter with three ports (2 inputs and 1 output), as seen in Fig.1. A multi-input converter is essentially a circuit structure that integrates various input voltage sources with varying voltage levels and delivers an output DC-load to a single output voltage source [16]. Fig. 2. is the block diagram of our proposed SEPIC-based MISO topology, where we have

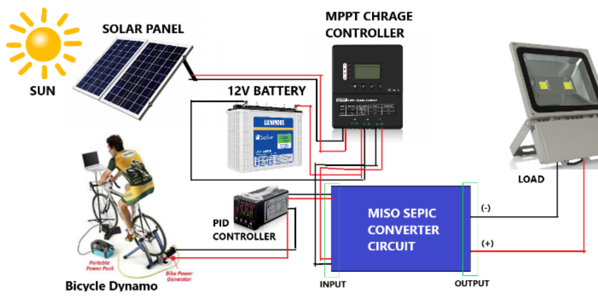

Fig. 2. Block Diagram of the proposed SEPIC-based MISO topology

considered two renewable energy sources as our input to the SEPIC circuit. In Fig. 3. we show the circuit schematic of our proposed SEPIC-based MISO architecture. The circuit diagram is a 2-D representation of the system as well as other circuit elements. It illustrates how each element should be

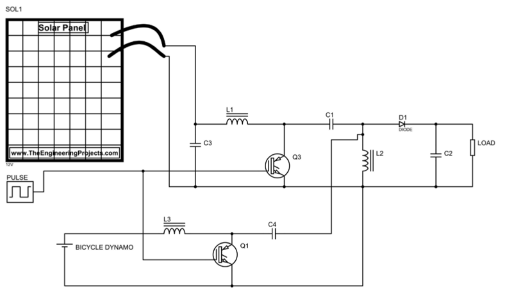

Fig. 3. Circuit Diagram of the proposed SEPIC-based MISO topology

interconnected appropriately. We inserted a voltage source in the circuit design for the bicycle dynamo.

IV. Hardware Implementation and Design Consideration

In this section, we have discussed the hardware implementation and design consideration of both SEPIC-based SISO and MISO topology. The converter formulas are shown in Table I. In addition, Table II contains the converter parameter. The prototype of the SISO topology is shown in Fig. 4. and the MISO topology in Fig. 5. Initially, to better understand the efficiency of the SEPIC topology, we implemented a SEPIC-based SISO topology. Afterward, we connected the two sources (Solar PV Module and Bicycle Dynamo) into a modified SEPIC circuit for our proposed MISO topology. It's worth mentioning that the digital multimeter was used to achieve all of the experimental data.

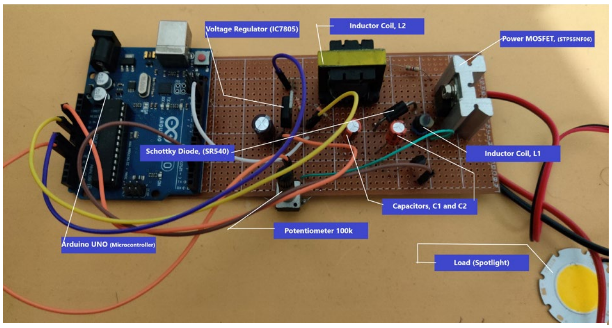

Fig. 4. Prototype of the general SEPIC-based SISO Converter Circuit

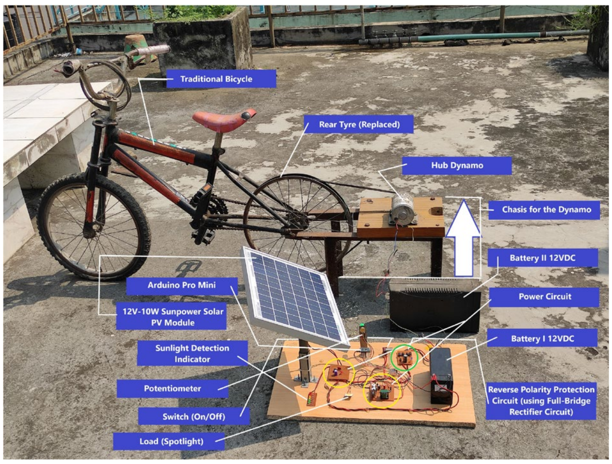

Fig. 5. Prototype of the proposed SEPIC-based MISO Converter Circuit

For the primary design approach of the hardware implementation, we have used handmade L_1 and L_2 inductor coils. Then we have used another coil, L at the load-end of the SEPIC circuit. Both the source is recorded at 12.1 V DC and they were further fed into the MISO topology. The duty cycle of this design approach was calculated at 81.4% through a reverse calculation once we got the optimum output of 53.3V. The two MOSFETs were switched using the Arduino ProMini at the exact same duty cycle. The frequency was set to 32kHz, just like the SISO topology. Additionally, we have used a 3 Amp Schottky diode, two MOSFETs, an N-P-N transistor (as the gate driver circuit) in the proposed system. To control the ripple effect, large coils have been incorporated into this circuit. We have also developed the MISO circuit in a Veroboard, similar to the SISO SEPIC converter circuit.

TABLE I. CONVERTER FORMULAS

Parameters	**SEPIC-based SISO Converter Circuit [17]**	**SEPIC-based MISO Converter Circuit [4]**
Duty Cycle (D)	$D = \frac{V_O}{V_O + V_{in}}$	$V_o = \frac{D_2V_2+D_{eff}V_1}{1-D_1}, D_{eff} = D_2 - D_1$
Inductors	$L = \frac{V_{out}D}{f\Delta i_{L_1}}$; $L_1 = L_2$	$L_1 = \frac{V_1D_2}{fI_{L_1}}, L_2 = \frac{V_2D_2}{fI_{L_2}}, L = \frac{D_1V_1+D_{eff}V_2}{fi_{L_1}}$
Capacitors	$C_1 = \frac{V_OD}{Rf(\frac{\Delta V_{C_1}}{V_{Out}})}$; $C_1 = C_2$	$C_1 = \frac{i_{L_1}}{fV_{C_1}}(1-D_1), C_2 = \frac{i_{L_2}}{fV_{C_2}}(1-D_{eff}), C = \frac{(D_1V_1+D_{eff}V_2)}{fRV_c}$

TABLE II. CONVERTER PARAMETER

Parameter	**SEPIC-based SISO Converter Circuit**	**SEPIC-based MISO Converter Circuit**
Input Voltage (V_{in})	12.22 V DC	V_1 = 12.1 V DC, V_2 = 12.1 V DC
Output Voltage (V_{out})	57 V DC	53.3 V
Output Power (P_{load})	10.15 W	10.1 W
Switching Frequency (f_s)	32 kHz	32 kHz
Duty Cycle (D)	0.823	D_1 = 0.8143; D_1 = D_2
Static Gain (q)	4.66	4.40
Inductors	L_1 = 630uH; L_1 = L_2	L_1 = 600uH, L_2 = 600uH, L = 615uH
Capacitors	C_1 = 47uF; C_1 = C_2	C_1 = 100uF, C_2 = 100uF, C = 2uF
Load resistance (R)	320 Ω	282 Ω

A. *Important Design Considerations of the SEPIC-based MISO Converter Circuit*

1) Gate Driver Circuit: The S8050 is the primary component utilized in the design of the gate drive circuit. Particularly, a driver stage is crucial while working with high-speed MOSFET switching and higher frequency ranges. A driver stage can stir the overall performance of the voltage conversion process. Accordingly, the necessity of integrating an additional driver stage emerges when we are using low voltage and current sources at the input side. The bipolar junction transistors can be of great use while designing a gate driver stage for any power electronic DC-DC converter circuits. As we're working in a higher frequency range at the control circuit, the BJT shows outstanding performance when we put it in between the output of the PWM signal pin and the gate of the MOSFET. In addition to that, we have also chosen the BJT as it has better voltage gain and a high current density. The converter components are shown in Table III.

TABLE III. CONVERTER COMPONENTS

Components	SEPIC-based SISO Converter Circuit	SEPIC-based MISO Converter Circuit
S, MOSFET	STP55NF06	N Channel, 60V, 0.01 Ω, 50A to 220/To-220 F_p
Inductor	L_1 = Handmade Iron Core Coil, L_2 = Ferric-Core/Double E-core Flyback	$L_1 = L_2$ (Handmade Iron Core Coil); L = Ferric-Core/Double E-core Flyback
Capacitor	$C_1 = C_2$ (Electrolytic Capacitor)	$C_1 = C_2$, C (Electrolytic Capacitor)
Microcontroller	Arduino UNO	Arduino Pro Mini
Diode	SR540	Schottky Diode ZRB582
Load	10W Spotlight	10W Spotlight
Battery	-	Lead Acid, 12 V 7.5 Ah
BJT/Transistor	S8050 NPN	S8050 NPN
Source	AC220V-to-DC12V 2A Switching Power Supply module	Solar Photovoltaic Module & Bicycle Dynamo

To fully enhance a power MOSFET, the minimum required charges come from the Gate-Source and Gate-Drain capacitances along with an external resistor [18].

2) DC Voltage Sources: The first renewable energy source is a Sunpower Solar PV Module with a rated voltage of 12 V DC and a 10W power. The second source is a Bicycle Dynamo generator, susceptible to changes in rotational speed.

3) Microcontroller: In the MISO topology, for the control circuit, we have used an Arduino Pro Mini based on ATmega328. It has 14 digital pins to be used as either input or outputs, six analog inputs, an on-board resonator, a reset button and holes for mounting pin headers [19].

4) Power Circuit Board: The power circuit of the MISO topology consists of two inductor coils at the source side and one inductor coil at the load side. The circuit has two coupling capacitors at the source side along with one capacitor at the load side to sweep the output ripple effect. It has a Schottky diode namely ZRB582. The reverse recovery time of the Schottky diode is very small and also the cut-in voltage for a Schottky diode is quite smaller [20]. A load resistor is also connected at the end of the power circuit.

5) Reverse Voltage Polarity Protection Circuit: We created a safety-protection circuit with four IN4007 diodes to prevent reverse-polarity issues from the bicycle dynamo output, as shown in Fig. 6. One of the most significant advantages of this circuit is that it rectifies the reverse polarity of the bicycle dynamo output voltage.

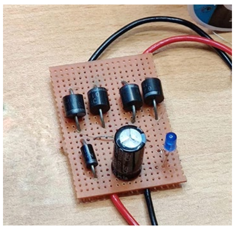

Fig. 6. Reverse-Voltage polarity protection circuit (implemented in the MISO prototype)

B. Hardware Results

Hardware results for both topologies can be seen in Table IV and Table V respectively.

TABLE IV. EXPERIMENTAL FINDINGS OF THE SEPIC-BASED SISO CONVERTER CIRCUIT

Parameter	Experimental Value
Input Voltage (V_{in})	12.22 V
Output Voltage (V_{out})	57 V
Load Resistance (R)	320 Ω
Duty Cycle (D)	82.3%
Input Current and Current through Coil-I (I_{L1})	0.68 A
Current through Coil-II (I_{L2})	0.08 A
Switching Frequency (f_s)	32 kHz
Output/Load Power, (P_{load})	11 W
Load Current (I_{load})	0.18A
Maximum Load Current ($I_{load(max)}$)	0.21A
Current through C_1 (I_{C1})	0.67A
Current through C_2 (I_{C2})	0.43A

TABLE V. EXPERIMENTAL FINDINGS OF THE SEPIC-BASED MISO CONVERTER CIRCUIT UNDER PRACTICAL FIELD TEST ANALYSIS

Parameter	Experimental Value
Input Voltage (V_{in})	12.1 V
Output Voltage (V_{out})	52.8 V
Maximum Output Voltage ($V_{out(max)}$)	53.3V
Load Resistance (R)	282 Ω
Duty Cycles, D1 and D2	81.43%
Input Current and Current through Coil-I (I_{L1})	0.19 A
Current through Coil-II (I_{L2})	0.19 A
Voltage across Coil-I (V_{L1})	-53.61 V
Voltage across Coil-II (V_{L2})	-53.61 V
Voltage across load (V_L)	53.6V
Voltage across Capacitor-I (V_{C1})	-12.11V
Voltage across Capacitor-II (V_{C2})	-12.11V
Voltage across load-end capacitor (V_C)	V_{out}
Voltage across load resistor, V_R	52.8V
Switching Frequency, (f_s)	32 kHz
Output/Load Power, P_{load}	10.1 W
Load Current, I_{load}	0.18A
Maximum Load Current, $I_{load(max)}$	0.19A
Current through Capacitor-I (I_{C1})	0.67A
Current through Capacitor-II (I_{C2})	0.43A

V. Software Simulation of the Mathematical Model of the SEPIC-based MISO Converter Topology

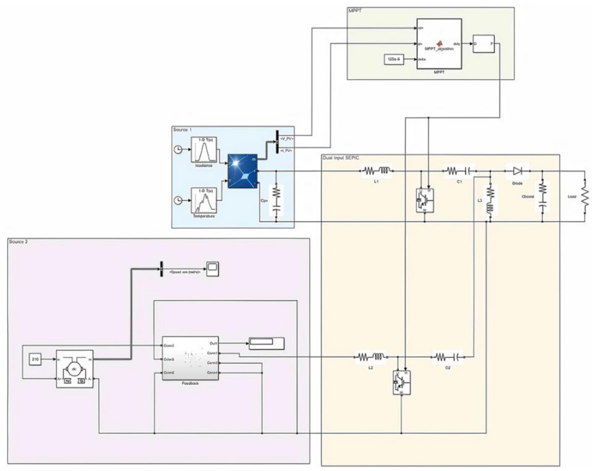

Fig. 7. The Proposed SEPIC-based MISO Converter Circuit Block Diagram viewed in MATLAB/Simulink

A MISO SEPIC system has been designed using MATLAB/Simulink as shown in Fig. 7. We have also analyzed several parameters of the system. An MPPT controller has been employed as a voltage regulator after Source-I, which is our Solar PV Panel. During the daytime, the Solar PV Panel generates a varied output due to the changes in solar irradiance. As a result, we must stabilize the output since voltage fluctuations entering the SEPIC-based MISO converter circuit will place additional strain on the power circuit components of the overall converter circuit. We have developed an algorithm for the MPPT controller block and thus it makes sure that it simultaneously stabilizes the output voltage of the Solar PV Panel to nearly 12 V DC. The output from the PV Panel depends on the irradiance and temperature of a particular time. The solar irradiance has been set using SWERA data. Our Source-II is a bicycle dynamo. For the dynamo portion DC machine have been utilized. A DC machine was used for the dynamo function. One of the pins of this DC machine has been utilized to provide input in the form of RPM. We calculate the rotating speed in rad/s in our simulation. A new feature has been added to allow for the measurement of metrics such as rotational speed. The remaining two pins are utilized to supply power to the main circuit that has been generated from mechanical energy. As the voltage we obtain from the dynamo is proportional to the rotational speed, the output voltage is highly volatile and we need to stabilize it. A feedback system using a buck converter has been integrated with the output-end of the dynamo block. The output of a bicycle dynamo is highly volatile, and it varies with changes in dynamo RPM. Finally, both of these sources' outputs are routed into the SEPIC converter, which gives power to the load. We have analyzed the system accuracy focusing on both winter and summer data. The in-depth result analysis will be discussed in the following section.

VI. Result Analysis

We have split up this section into two segments, the first one is the hardware result analysis and the latter one is the software result analysis. In the hardware result analysis, we have compared the results between the SISO topology and the MISO topology in terms of efficiency, voltage gain and duty cycles. For, the software simulation result analysis, we have again compared the results between SISO topology and MISO topology based on Summer and Winter data. The solar irradiance data is taken from Bangladesh's final Solar and Wind Energy Resource Assessment study (SWERA).

A. Hardware Result Analysis

In Table VI, we have shown a comparative hardware result analysis for both the MISO topology and the SISO topology. The highest output voltage for the SEPIC-based MISO converter circuit is 53.3 V with a duty cycle of 81.4% while having an efficiency of 91.6% with a static gain of 4.39.

TABLE VI. Comparison: MISO Topology vs SISO Topology (Duty Cycle, Efficiency and Voltage Gain)

SEPIC-based MISO Converter Circuit			**SEPIC-based SISO Converter Circuit**		
D_M	***Efficiency (%)***	***Voltage Gain***	***D_S***	***Efficiency (%)***	***Voltage Gain***
0.4716	13.24	0.89	0.50	5.00	1
0.5754	22.11	1.35	0.55	7.00	1.22
0.6543	31.84	1.89	0.60	13.00	1.49
0.7238	46.14	2.66	0.70	29.00	2.32
0.7515	53.89	3.02	0.79	60.00	3.97
0.7804	65.75	3.55	0.81	61.00	4.32
0.8029	82.20	4.07	0.82	64.00	4.54
0.8149	91.64	4.39	0.823	65.00	4.66

On the contrary, the SISO converter circuit is having an output voltage of 57 V with a duty cycle of 82.3%. The efficiency rate for the SISO converter circuit is 65% with a static gain of 4.66.

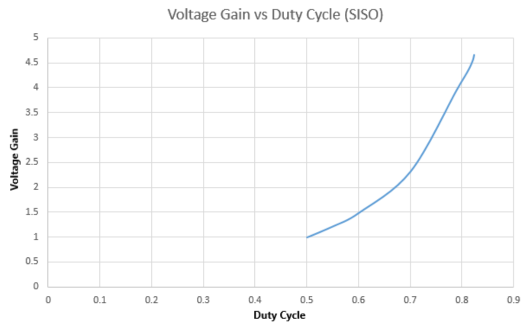

Fig. 8. Graph of the SEPIC-based SISO Topology: Voltage Gain vs Duty Cycle

The Voltage Gain vs Duty Cycle and Efficiency vs Duty Cycle plots for both topologies are shown in Fig. 8. up to Fig. 11.

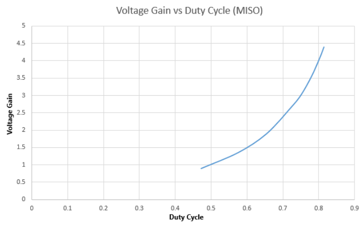

Fig. 9. Graph of the SEPIC-based MISO Topology: Voltage Gain vs Duty Cycle

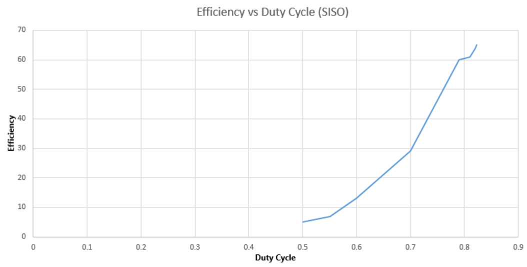

Fig. 10. Graph of the SEPIC-based SISO Topology: Efficiency vs Duty Cycle

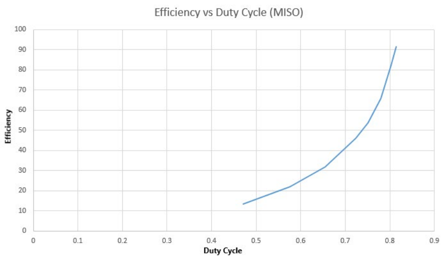

Fig. 11. Graph of the SEPIC-based MISO Topology: Efficiency vs Duty Cycle

B. *Software Result Analysis*

As part of this research, several simulation-based tests are conducted. The first step was to develop a mathematical model of the standard SISO SEPIC and then a MISO SEPIC. Then we put through them into a MATLAB/Simulink simulation to perform system analysis. Software Simulation parameters of the SEPIC-based MISO converter circuit is shown in Table VII.

TABLE VII. SOFTWARE SIMULATION PARAMETERS OF THE SEPIC-BASED MISO CONVERTER CIRCUIT

Parameters	Values
L_1,L	336 µH
L_2	100 µH
C_1, C	504 µF
C_2	100 µF
Switching Frequency	32 kHz
Load	25 Ω

1) Software Simulation Result of MISO Topology (Summer):

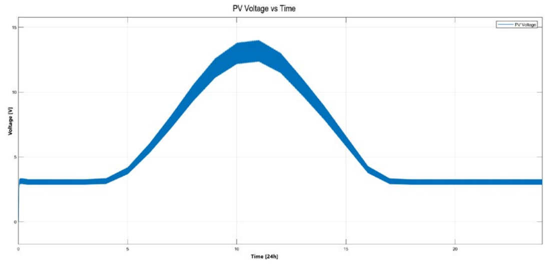

Fig. 12. MISO Topology: PV Output Voltage and Current (Summer)

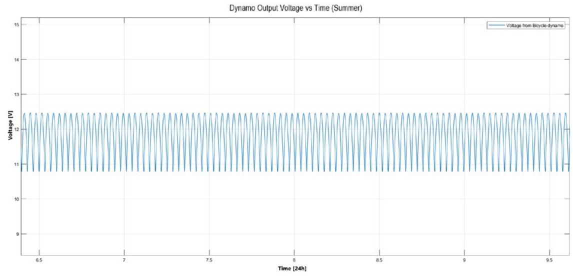

Fig. 13. MISO Topology: Bicycle Dynamo Output Voltage and Current (Summer)

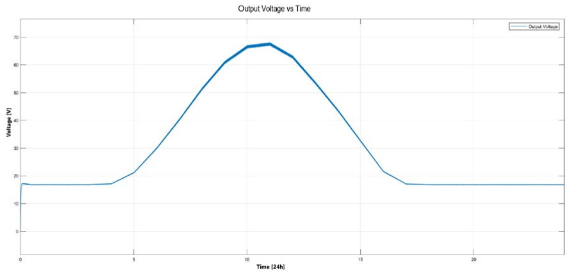

Fig. 14. MISO Topology: Output Voltage (Summer)

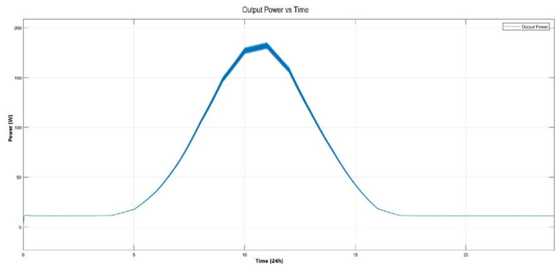

Fig. 15. MISO Topology: Output Power (Summer)

In this section, the plots of PV Output Voltage and Current, Bicycle Dynamo Output Voltage and Current, MISO converter circuit's Output Voltage and MISO converter circuit's Output Power for the summer season has been shown in Fig. 12. up to Fig. 15.

2) Software Simulation Result of MISO Topology (Winter):

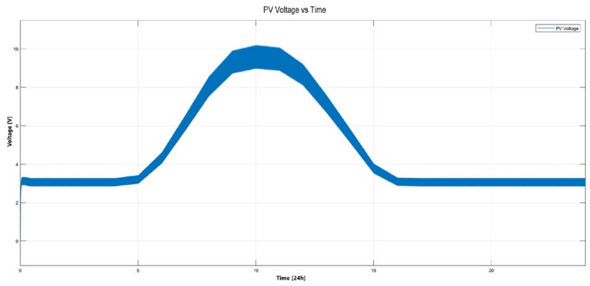

Fig. 16. MISO Topology: PV Output Voltage and Current (Winter)

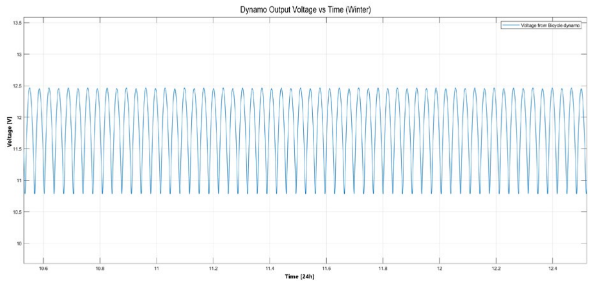

Fig. 17. MISO Topology: Bicycle Dynamo Output Voltage and Current (Winter)

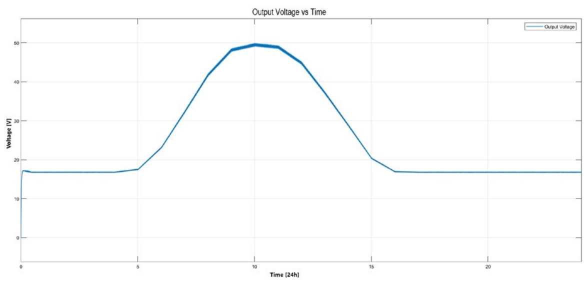

Fig. 18. MISO Topology: Output Voltage (Winter)

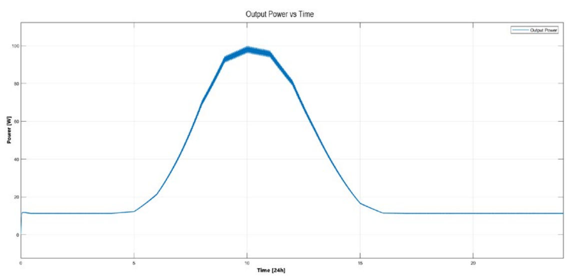

Fig. 19. MISO Topology: Output Power (Winter)

In this section, the plots of PV Output Voltage and Current, Bicycle Dynamo Output Voltage and Current, MISO converter circuit's Output Voltage and MISO converter circuit's Output Power for the winter season has been shown in Fig. 16. up to Fig. 19.

The hardware result analysis and the software analysis results provide us with significant insights. Prior to the practical field test analysis of the MISO prototype, we performed the Solar PV Panel's (short-circuit current, open-circuit voltage, cells temperature, humidity, wind speed, etc.) outdoor test analysis on September 20, 2021. We also measured the output current and output voltage of the Bicycle Dynamo with varying RPM values. For the hardware implementation part, we explored the design considerations of both the SEPIC-based SISO topology and MISO topology. The practical field test analysis of these prototypes shows that the maximum efficiency of the MISO prototype is 91.64% whereas the maximum efficiency of the SISO prototype is only 65%. There is a huge trade-off between these two practical values. Although the SISO prototype has a far larger maximum voltage gain, the difference is trivial. In a similar manner, we used MATLAB/Simulink software simulation to analyze the outcomes throughout the summer and winter seasons. Surprisingly, the simulation results also show that the efficiency of our proposed MISO prototype has better precision and accuracy over the SISO topology. In summary, we can conclude that our suggested MISO prototype model is trustworthy and viable when two renewable energy sources are used as inputs.

VII. Economic Feasibility and Sustainibility Analysis

Our SEPIC-based MISO prototype can generate power up to 38.3 KWh/year. We used a 10 W spotlight as a load for our prototype in this computation (just like our practical field test analysis). We also considered in a total sun-hours of 5 hours for solar PV Panel energy output and an additional two hours for bicycle dynamo electricity generation. The more we use the pedaling power method using the bicycle, the more power it will generate. According to our calculation, the highest RPM we found for bicycle is 600 and for that RPM, the obtained current was 2.3 A. Therefore, a 12 V DC bicycle dynamo will be able to produce 27.6 W each hour.

TABLE VIII. Estimated Budget for the MISO Prototype

Items	Approximate Cost (in BDT)	Approximate Cost (in Dollar)
One PV Panel (12 V-10 W)	2500	$29.28
Bicycle Dynamo Generator (Motor, Welding)	1500	$17.53
MPPT Controller	520	$ 6.00
Lead acid battery 12 V-7.5 Ah	100	$11.69
SEPIC Configuration (Breadboard, Resistors, Inductors, Diode, BJT, IJT, MOSFET and Capacitors)	3000	$ 35.06
Feedback Controller	4500	$52.59
Total	13020	$152.12

On the contrary, if we consider a 10 W PV Panel in its maximum power generation of 5 hours/day, it will be able to produce nearly 50 W power per day (considering intermittence conditions and maximum sun-hours in a single day). The estimated budget that will be needed to construct our prototype is about 13,020 BDT or $152.12. The estimated budget breakdown of the MISO prototype has been shown in Table VIII. The system lifespan can be approximated to around 25 years if regular maintenance is ensured. This prototype is emission-free ensuring zero CO_2 and other greenhouse gases. It has no health risks for the operator. It doesn't affect the environmental elements. Additionally, the electricity bill can be curbed using this prototype as we are promising an off-grid energy harvesting solution. The functionality of this prototype is very simple and user-friendly. Teaching the operating modes of this prototype to any village/distant island natives who do not have the minimal minimum of literacy will not be a problem.

VIII. Conclusion & Future Work

This paper proposes a multi-input–single-output (MISO) DC-DC SEPIC converter. A comparison of the SISO and MISO topologies has been carried out. Observing the result analysis, we deem that the MISO topology would be undeniably a suitable technology to ensure maximum energy-harvesting through a clean, tangible, and cost-effective approach for isolated islands of Bangladesh.

In our project, we can integrate other renewable energy sources like wind-turbine, biomass wastes, geothermal energy, etc. for large-scale appliances. Additionally, in our hybrid MISO prototype, we may combine the national grid with the Solar PV module. The load will get a constant power supply either from the national grid or from solar power. In this case, the national grid will be in a cutoff position during utter sunlight availability. An intelligent Fuzzy logic controller system can be designed as an energy management system for this prototype. It is basically an intelligent management tool based on switching technology that can automate input sources connected with the load. It's still under the development phase. To maximize the supply from Solar Panel and save up maximum energy coming from the national grid, this logic controller can play a vital role. It can save up to 80% energy of the national grid during daytime [21]. A rule-based control system of this controller will be a suitable method to measure and compare the load demand at various times throughout the day/night. Moreover, the excess power generated from the Solar PV Panel can be stored in the utility grid if a feedback system can be developed using a lead-acid battery that will be fixed with the transformer by the utility company.

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