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Implementation Smart Automatic Transfer Switch Multi-Input Multi-Output (MIMO) On DC House

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ABSTRACT

In the development of technology, the specialization in New and Renewable Energy (NRE) is increasing, this is supported by the infrastructure of using NRE as a need for transportation of electric cars, electric bicycles, electric vehicle charging stations, home electricity needs, and the fulfillment of industrial needs. The electrical basis of the system is DC electricity where it is more efficient because there is no need to convert to AC electricity. In this study, it supports the transition and full use of DC electrical energy with an ATS system with various sources and equipped with a variable output of DC voltage used. The test results showed that the solar panels performed optimally at a voltage of 13.4 V and a current of 0.8 A, while the wind turbine had a fluctuating performance with a voltage between 7.2 V to 14.2 V and a current of 0.21 A to 0.5 A. Picohydro had a stable voltage in the range of 11.4 V to 13.2 V, but the current was low due to limited water flow. PSUs, as a backup power source, show stable performance with voltages between 14.3 V to 14.5 V and currents of 1.05 A to 1.3 A. MIMO ATS (Automatic Transfer Switch) systems are proven to be able to prioritize resource priorities to maintain power stability.

1. Introduction

In recent decades, global challenges related to climate change and limited supply of fossil energy have prompted efforts to transition to the use of renewable energy. Conventional energy such as oil, coal, and natural gas are still the main supporters of the world's energy needs, but they have been proven to contribute to greenhouse gas emissions and cause negative impacts on the environment. In response to this situation, many countries, including Indonesia, have begun to switch to more environmentally friendly renewable energy sources such as solar, wind, and water[1], [2], [3], [4], [5], [6]. However, this transition requires the right infrastructure to ensure the efficient and stable use of renewable energy.

Innovations that supports this energy transition is the development of DC Homes, direct current (DC)-based home systems designed to utilize various renewable energy sources. Initially, DC homes were developed for off-grid rural electrification needs using one or more small-scale renewable energy sources along with centralized battery systems and DC power distribution systems [3], [5]. Over time, the concept of DC homes expanded to include urban homes, smart homes, zero-carbon homes, and other platforms that require an efficient DC electrical system. The use of DC power is more compatible with renewable energy devices such as solar panels and wind turbines, which allows for more efficient integration of various renewable energy sources. However, to maximize efficiency, an adaptive approach to energy inputs and outputs is needed [5].

One of the important solutions in the development of DC home applications is the multiple-input multiple-output (MIMO) Automatic Transfer Switch (ATS) system, which allows the simultaneous connection and control of multiple energy sources, allowing for optimal use of various renewable energy sources based on availability and demand. ATS MIMO can also manage power distribution to various electrical devices more efficiently by integrating Multi Inputs (Solar, Wind Turbine, MicroHydro, PSU)[7]. In addition to multi-input, the source also takes into account in terms of continuity from the source such as obstacles blocked by cloudy weather, lack of wind gusts, and hampered by drought or channel disruption. So the ATS functions as a source transfer control using the ESP 32 control for resource transfer management [8], [9], [10], [11], [12]. Meanwhile, the output part that goes to the load (5V, 12V, 9V, 18V, 24V) to meet the load needs[13].

In this study, tests were carried out to analyze the losses that occurred during the energy conversion process in the Multi Input system. This system combines various energy sources, namely solar power generation (Solar)[14], [15] ,Wind Power (Wind Turbine)[16], Hydropower (Microhydro) [17] and Power supply unit (PSU) with an input voltage of 12 V. Energy from these sources is then distributed to loads with varying output voltages, namely 3.7 V, 5 V, 12 V, and 24 V[18]. This conversion and distribution process is tested to determine the extent to which the efficiency of the system is affected by variations in output voltage, as well as to identify the level of energy losses that occur at each stage of conversion and distribution.

2. Research Methods

The ATS MIMO process is divided into 4 Processes, namely Input, Backup, Control and output where they have their respective roles. Input as a source of generation (Solar, Wind turbine, PicoHydro, PSU);[19] Backup as to process energy from generation to be stored to the battery and distributed to the load[20], [21], On the Control there are four relays to read the voltage using the DC Voltage sensor and process it based on the priority of 10.5v or the standard limit of the Charger controller[9][22] thus activating the relay and distributing to the Load Output varying voltage (3.7v , 5v, 12v dan 24 v)[18] .

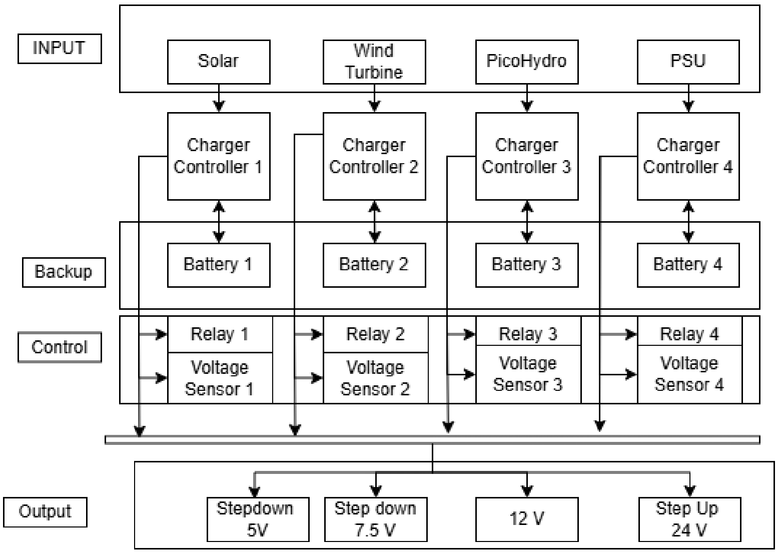

Figure 1. System ATS MIMO

In the process diagram in Figure 1 of the ATS MIMO S1 process, energy generation using solar panels (Soalr), S2 is energy generation using wind turbines (Wind Turbine), S3 is energy generation using small-scale hydropower (picohydro), and S4 is using a power supply unit or power supply unit. The processes and algorithms embedded in the ESP32 are described in Table 1 which contains the order of priority of ATS MIMO

Tabel 1: Priority ATS MIMO

Priority	S1	S2	S3	S4
1	ON	OFF	OFF	OFF
II	OFF	ON	OFF	OFF
III	OFF	OFF	ON	OFF
IV	OFF	OFF	OFF	ON
OFF	OFF	OFF	OFF	OFF

The order of priority of ATS MIMO in Table 1 will be explained by the following summary, where S is the Source

1) Priority I: Source 1 > 10.5 Vdc then S1 is used as the source for the load supply
2) Priority II: Source 2 > 10.5 Vdc then Source 2 is used as the source for the load supply
3) Priority III: Source 3 > 10.5 Vdc then Source 3 is used as the source for load supply
4) Priority IV : Source 4 > 10.5 Vdc then Source 4 is used as a source for load supply
5) Off condition: when all sources have a voltage value < 10,5 Vdc, the system will go out because if it is run it will damage the equipment.

3. Results and Discussion

3.1 Experiment Losses on MIMO Conversion

The test of losses in MIMO conversion with loads varying voltages aims to analyze how much loss occurs in MIMO system conversion, especially when the load given has different voltages. In this test, loads with varying voltages are tested to see the impact of the input power and output power. Changes in load voltage can affect conversion performance, causing distortion or interference that impacts the power received. The results of these tests can provide insight into the extent to which voltage fluctuations affect losses in MIMO conversions and help in designing systems that are more resistant to voltage variations to ensure optimal performance under real-world conditions.

Tabel 2: Testing Losses ATS MIMO

NO	Load	V in	V out	I in	I out	Loses
1.	Dynamo seri (12V)	12V	11,5V	0,21A	0,10A	1,37 watt
2.	Led 12V	12V	11,7V	0,20A	0,07A	1,58 watt
3.	Led 12V Pararel	12V	11.3V	0,28A	0,20A	1,1 watt
4.	Dynamo PG45	12V	11,4V	0,49A	0,45A	0,75 watt
5.	Dynamo 5V	12V	3,4V	0,16A	0,14A	1,44 watt
6.	Dynamo seri (7,5V)	12V	5,4V	0,44A	0,42A	3,01 watt
7.	Indikator lamp Pararel (24V)	12V	24V	0,24A	0A	2,88 watt
8.	Indikator Lamp Tunggal (24V)	12V	24V	0,15A	0A	1,8 watts
9.	Buzzer Pararel (24V)	12V	24V	0,24A	0,01A	2,64 watt
10.	Buzzer Single (24V)	12V	24V	0,17A	0A	2,040 watt

The use of buck and boost converters in the system affects losses significantly, depending on the design and efficiency of each converter. At loads that require voltage drops such as the 5V Dynamo and the Dynamo series (7.5V), buck converters show quite high losses because sharp voltage drops increase the input current, thus increasing internal resistance and switching losses. In contrast, at loads that require increased voltage such as Indicator Lights and Buzzers (24V), the boost converter generates losses caused by switching losses on the mosfet, losses on the inductor, and greater input current. The main factors that affect the efficiency of the converter are the quality of components such as inductors, mosfets, and diodes, as well as adequate thermal design to manage heat. With the average converter efficiency below 90%, losses become significant, especially at high current loads.

3.2 Generation Performance Test on ATS DC MIMO

In the generation performance test, it is carried out to evaluate the potential of renewable energy, which includes solar, wind turbines, picohydro, and PSU, when connected to the MIMO ATS.

Tabel 3: Measurement result of generation source ATS MIMO DC

NO	V in PV	I in PV	Vin WT	I in WT	V in Picohydro	I in picohydro	V in PSU	I in PSU
1.	13,2	0,8	14,2	0,5	12,2	0,6	14,4	1,2
2.	13,4	0,76	10,2	0,21	12,1	0,54	14,3	1,1
3.	13,1	0,74	8,7	0,24	12,4	0,4	14,4	1,25
4.	13,02	0,71	8,4	0,23	12,3	0,4	14.41	1,3
5.	13,04	0,68	9,2	0,23	12,1	0,31	14,42	1,24
6.	13,04	0,67	9,15	0,23	11,4	0,34	14,35	1,25
7.	12,2	0,65	9,4	0,23	13,2	0,36	14,42	1,27
8.	12,9	0,54	8,2	0,22	13,2	0,37	14,41	1,3
9.	12,7	0,35	8,1	0,24	13,1	0,37	14,5	1,2
10,	11,4	0,37	7,2	0,22	12,4	0,20	14,28	1,05

Based on the available data, the solar panels show optimal performance in sunny conditions, producing the highest power at 0.8 A current and 13.4 V voltage, but the power decreases when the intensity of sunlight decreases. Wind turbines, on the other hand, are highly dependent on wind speed, with voltages varying between 7.2 V to 14.2 V and currents between 0.21 A to 0.5 A, showing highly fluctuating performance depending on wind conditions. Meanwhile, picohydro shows a relatively stable voltage (11.4 V to 13.2 V) but the current generated is lower and is affected by the strength of the water flow, which tends to decrease if the water flow is limited. The PSU serves as a very stable backup power source, with a voltage of about 14.3 V to 14.5 V and a current between 1.05 A to 1.3 A, providing greater and more stable power when other sources are not optimal enough. Overall, the system works well when there is an adequate source of renewable energy, but the PSU is essential as a backup power source to maintain the stability of the system in adverse weather conditions or when the renewable source is not functioning optimally.

3.2 Experiment Performance Switch ATS DC MIMO

ATS MIMO performance testing is carried out directly by paying attention to environmental conditions that affect ATS performance. For example, in Solar conditions, when cloudy, rainy, or nighttime weather causes a voltage drop, a battery is needed as a backup. This is reflected in the reading on column S1 or voltage sensor 1, where the priority source in the relay will illuminate. Likewise with wind turbines; when the wind turbine is operating optimally, but there is no wind, the voltage sensor 2 (S2) will detect a voltage drop affecting the relay reading. In pico hydro conditions, performance depends on water flow, where dry seasons or obstacles in the pico hydro path can degrade its performance. Nonetheless, the picohydro source and battery can still back up, which is reflected in the voltage sensor reading 3. For PSUs, under optimal conditions, voltage sensor 4 (S4) will show good performance, but if the PSU goes out, the battery will take over. If all energy sources go out, then the system will be inactive.

Tabel 4: Switch Results Based on Conditions

No.	Souece	Condition	Energy source used	S1	S2	S3	S4
1	Solar	Hot and sunny	Solar	V			
2		Cloudy/rainy/night	Battery	V			
3	Wind turbine	Wind Turbine optimal	Wind turbine		V		
4		No wind	Battery		V		
5	Pico Hydro	Pico Hydro optimal condition	Picohydro			V	
6		Blockage in waterways/dry season	Battery			V	
7	PSU	PSU Optimal	Power Supply Unit (PSU)				V
8		PSU Off	Battery				V
9	Off System	All systems Disable		OFF			

4. Conclusion

Loss tests on MIMO conversion systems show that load voltage variations affect conversion efficiency, especially at loads that require different voltages. At loads such as the 5V Dynamo and the 7.5V series Dynamo, the buck converter produces significant losses due to sharp input current surges. Meanwhile, at loads such as Light Indicators and 24V Buzzers, boost converters suffer considerable losses due to switching losses. The test results show that the solar panels operate optimally at a current of 0.8 A and a voltage of 13.4 V, while wind turbines generate voltages that vary between 7.2 V to 14.2 V and currents between 0.21 A to 0.5 A, with very unstable performance. Picohydro has a relatively constant voltage, ranging from 11.4 V to 13.2 V, but produces lower currents due to limited water flow. The PSU, with a stable voltage between 14.3 V to 14.5 V and a current of 1.05 A to 1.3 A, serves as the main backup power source to maintain the stability of the system when the renewable energy source is not functioning optimally, so that the system can still operate under various conditions.

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