Simulation of a New Proposed Voltage-Base Self-Intervention Technique with Increment and Decrement Voltage Conduction Method to Optimize the Renewable Energy Sources DC Output

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***Abstract*— A simple Voltage-Base Self-Intervention technique is introduced in this paper to perform the switching between the connected distributed generation renewable energy sources. The Voltage-Base Self-Intervention technique fetch maximum power from either the solar photovoltaic or wind energy systems under inhomogeneous climate conditions and output stable voltage for DC – AC inverter and DC – DC Boost Converter. In order to fetch the maximum power, the proposed Voltage-Base Self-Intervention technique is composed with the voltage quantification and the increment and decrement hierarchical voltage management and control strategy algorithm. The voltage quantification and the increment and decrement hierarchical voltage management and control strategy algorithm is developed to ensure the DC bus voltage from the solar and wind renewable energy sources can be measured efficiently and effectively during the voltage conduction to perform the Voltage – Base Self - Intervention. To validate the performances of the proposed Voltage-Base Self-Intervention technique for solar – wind renewable energy sources, PROTEUS simulations are presented in this paper. Simulation results shows that the proposed technique effectively perform the Voltage – Base Self – Intervention between the distributed generations solar – wind renewable energy sources during the voltage conduction.**

Keywords-renewable energy sources; solar photovoltaic; wind energy; voltage – base; self - intervention

I. INTRODUCTION

Renewable energy sources have gained great attention because of the disadvantages of fossil fuels based electricity power generation systems [1]. Therefore, in recent years renewable energy sources based system have been given great emphasis. The renewable energy sources power systems for electricity generations are among with minimal negative impact on the environment. Hence, among fastest growing renewable energy sources power system are undoubtedly the solar photovoltaic and wind energy system [2], [3], [4]. Therefore, the state-of-the-art of the solar photovoltaic and wind energy systems as a hybrid power system development is to compensate between each another during their intermittency period [5]. System proposed and research conducted such as in [2], [6], [7], [8], [9], [10], [11] introduces the method of controlling the renewable energy sources at the Distributed Generation (DG). All of these researches have proposed new methods with the attention to increase the penetration level at the intermittent of renewable energy sources. In [12] has been mentioned, determination of an optimum hybrid renewable energy system highly dependable on the adaptability of renewable energy sources and energy management system to optimize the control strategy.

In this paper, a solar – wind renewable energy sources combinational are proposed at the DG level. As mentioned in [13], due to the intermittent nature of the solar – wind renewable energy sources, both sources requires a control strategy to compensate each other during climate change or intermittent period. Hence, a new voltage-base self-intervention technique is proposed to perform the control strategy for solar – wind renewable energy sources at the DG level to fetch maximum power under inhomogeneous climate and perform the switching control during the voltage increment and decrement during voltage conduction. The increment and decrement hierarchical voltage management and control strategy algorithm is proposed to continuously sense and measure the input voltages of solar – wind renewable energy sources based on the voltage quantification to optimize the renewable energy sources Direct Current (DC) output.

Therefore following the introduction, an outline of the voltage-base self-intervention technique principle operation is discussed in Section II. In Section III, the method of the increment and decrement hierarchical voltage management and control strategy algorithm base on the voltage quantification is designed and developed. The algorithm is developed based on quantifying the 14 Volt input voltage of the solar - wind renewable energy into FIVE stages and voltage – base self – intervention operation and optimization is discussed. The results and discussion in Section IV presents the PROTEUS simulation and calculation to validate the methodology in Section II. Finally Section V will include some conclusion remarks.

II. VOLTAGE – BASE SELF - INTERVENTION

The voltage-base self-intervention technique is proposed to sense and measure the input voltage from the solar – wind renewable energy sources. In the proposed technique, two voltage dividers are connected after the output voltage system stabilizer. The stabilized output voltages of solar – wind renewable energy sources are conduct through the

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voltage dividers, continuously sensed and measured using voltage dividers.

Fig. 1 shows the relationship between the PIC16F877A microcontroller analogue to digital (ADC) voltage (V_{pic}) and the solar – wind renewable energy sources $(V_{solar-wind})$ voltage. Fig. 1 described that 1 Volt sensed and measured at the ADC is equivalent to 2.8 Volt input voltage from the solar – wind renewable energy sources. Next, the setup for ADC unit sensitivity per bit voltage $(1bitVolt_{pic})$ and voltage divider circuits operation is discussed. The process to determine $1bitVolt_{pic}$ is important to sense and measure the voltage changes of input voltage of the solar – wind renewable energy sources voltage during voltage conduction period.

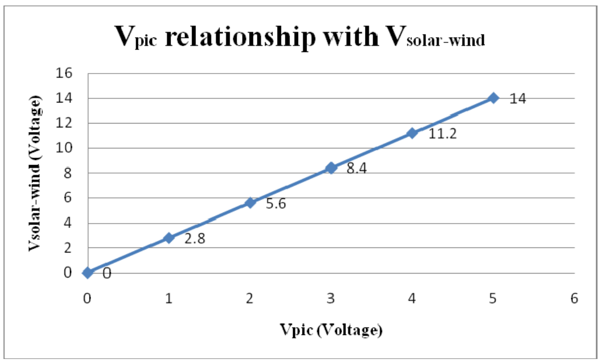


Figure 1. Vpic (Voltage) proportion relationship with Vsolar-wind (Voltage).

Where,

The PIC16F877A microcontroller has 10 bit resolution of ADC, hence, $2^{10} = 1024\text{bits}(0-1023)$

$$InputVoltage/bit = \frac{V_{solar-wind}Volt}{1024bits} \tag{1}$$

$$= 0.01367Volt$$

$$Numberofbits = \frac{V_{solar-wind}Volt}{InputVoltage/bit} \tag{2}$$

$$= 205bits$$

Therefore,

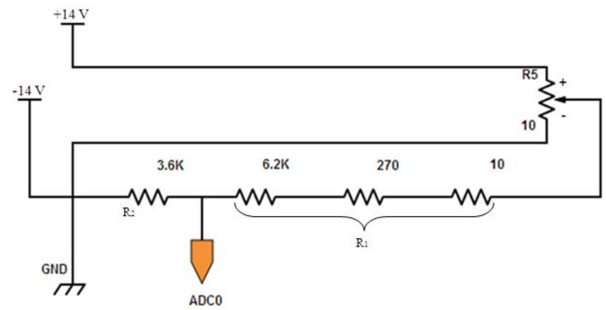
$$1bitVolt_{pic} = \frac{1Volt_{pic}}{205bits} \tag{3}$$

$$= 0.0049Volt$$

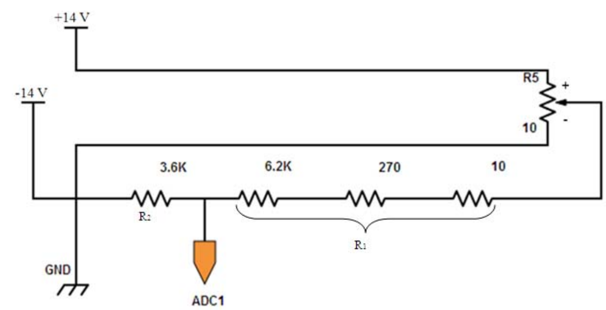
$$ADCVolt = Numberofbits \times 1bitVolt_{pic} \tag{4}$$

Therefore, the calculation shows that $InputVoltage/bit$ for $V_{solar-wind}$ is equivalent to 0.01367 Volt. In particular, the $1bitVolt_{pic}$ is equivalent to 0.0049 Volt and 205 bits are required for 2.8 Volt of $V_{solar-wind}$ input voltage.

The voltage dividers circuit setup is shown in Fig. 2, stabilized 14 Volt voltage form $V_{solar-wind}$ is used to calculate the resistors, R_1 and R_2 values.



(a)



(b)

Figure 2. Solar – Wind Voltage Divider Circuits – Voltage - Base.

Where,

$$V_2 = \frac{R_2}{R_1 + R_2} V_S \tag{5}$$

Lets $V_S = 14Volt$

$V_{pic} = 5Volt$

Let's assume, $R_2 = 3.6k\Omega$

$$5 = \frac{3.6k\Omega}{R_1 + 3.6k\Omega} \times 14Volt$$

$$5 = \frac{50400}{R_1 + 3.6k\Omega}$$

$$R_1 + 3.6k\Omega = \frac{50400}{5}$$

$$R_1 = 10.08k\Omega - 3.6k\Omega$$

$$= 6.48k\Omega$$

$$= 6.2k\Omega + 270\Omega + 10\Omega$$

Referring to Fig. 2, $V_{solar-wind}$ will output maximum of 14 Volt when $R_5 = 10\Omega$, equivalent to 5 Volt at V_{pic}. And, when $R_5 = 0\Omega$ then V_{pic} is equal to 0 Volt.

In follows that, section II has addressed the methodology for voltage – base self – intervention technique using the voltage divider concept. With that, in the next section the self – intervention controllability based on voltage quantification and the increment and decrement hierarchical voltage management and control strategy algorithm are discussed.

III. Self – Intervention Controllability

The self – intervention controllability is composed voltage quantification and the increment and decrement hierarchical voltage management and control strategy algorithm. The aim is to allow the solar – wind renewable energy sources self – intervene based on the sensed and measured input voltages. Voltage quantification is dividing the 14 Volt $V_{solar-wind}$ input voltage into FIVE stages as shown in Table 1.

TABLE I. Voltage Quantification Solar – Wind Renewable Energy Sources

Stages	Sources	Conditions
1.	System Initialization	
2.	Solar Energy (SE)	12 Volt < SE ≤ 14 Volt
	Wind Energy (WE)	12 Volt < WE ≤ 14 Volt
3.	Solar Energy (SE)	9 Volt < SE ≤ 12 Volt
	Wind Energy (WE)	9 Volt < WE ≤ 12 Volt
4.	Solar Energy (SE)	5 Volt < SE ≤ 9 Volt
	Wind Energy (WE)	5 Volt < WE ≤ 9 Volt
5.	Solar Energy (SE)	0 Volt < SE ≤ 5 Volt
	Wind Energy (WE)	0 Volt < WE ≤ 5 Volt

Fig. 3 shows the proposed architecture of the solar – wind renewable energy sources using the PIC16F877A microcontroller. ADC0 and ADC1 are used to sense and measure the input voltages increment and decrement for $V_{solar-wind}$ and voltage quantification is used to perform the hierarchical voltage management and control strategy algorithm as shown in Fig. 4.

In the following the voltage – base self – intervention technique process and operation is explained based on the increment and decrement hierarchical voltage management and control strategy algorithm in Fig. 4.

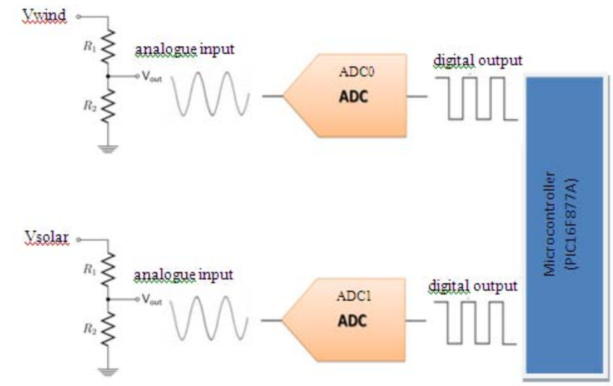


Figure 3. Solar - Wind Self - Intervention using ADC channel of PIC16F877A Microcontroller.

Stage 1: During the system start-up, the system will sense and measure the $V_{solar-wind}$ voltages. If no voltage is available, then the system will be halted.

Stage 2: If $V_{solar-wind}$ voltages are at 12 Volt < solar – wind ≤ 14 Volt, then solar will be set as primary energy source supplier meanwhile wind will be set as secondary energy source supplier. In fact, if the solar input voltage is not available or less than 12 Volt, then wind will be the primary energy source supplier with the condition wind input voltage is 12 Volt < wind ≤ 14 Volt and solar will be set as secondary energy source supplier with condition solar input voltage is 5 Volt < solar ≤ 12.

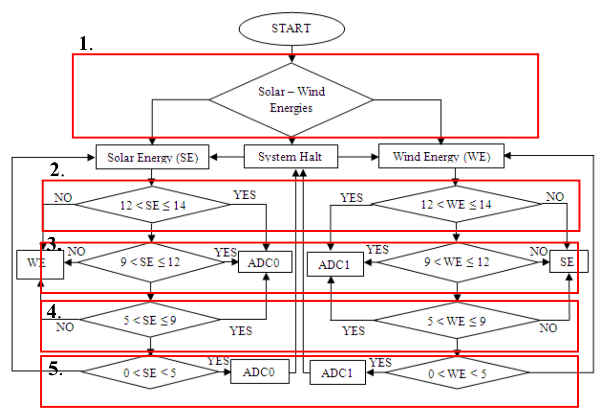


Figure 4. Increment and Decrement Hierarchical Management and Control Strategy Algorithm.

Stage 3 and 4: The system operation in stage 2 is also used for stage 3 and 4 when performing the increment and decrement hierarchical voltage management and control strategy algorithm.

Stage 5: During this stage, the $V_{solar-wind}$ voltages are less than 5 Volt. Hence, the ADC0 and ADC1 will send HIGH signal to HALT the system.

IV. Results and Discussions

This section presents the design of voltage dividers circuit in PROTEUS simulation software. The ADC0 is connected to the wind energy input voltage and ADC1 is connected to the solar energy input voltage. In this simulation, cell batteries are used as a condition to provide the solar – wind voltage dividers circuit with constant 14 Volt. Each condition described in Table 1 is demonstrated and the voltage – base self – intervention simulation test results are captured.

Fig. 5 shows 14 Volt input voltage from $V_{solar-wind}$ as described in stage 1 of Table 1.

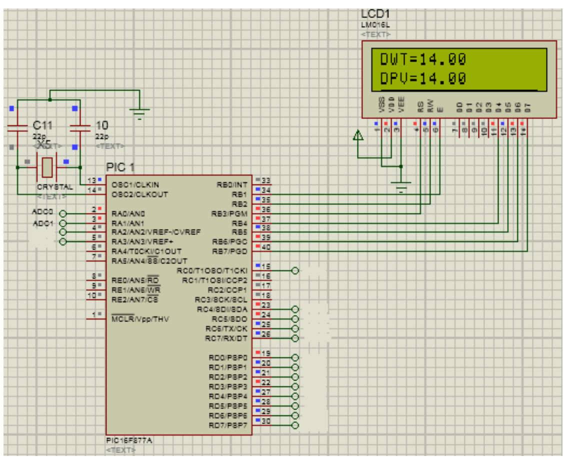
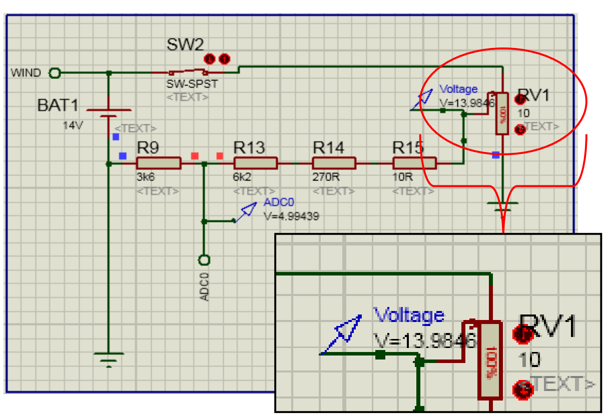


Figure 5. Solar – wind analogue voltage reading at 14 Volt.

Fig. 5(a) is the wind voltage divider circuit connected to the ADC0 and Fig. 5(b) is the solar voltage divider circuit connected to the ADC1 of the PIC16F877A microcontroller.

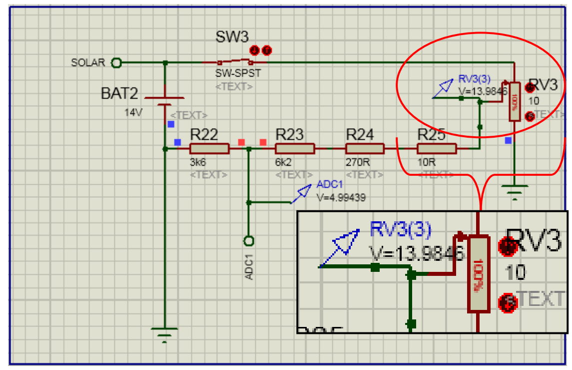
i. Condition 1: 12 < wind ≤ 14



(a)

Fig. 5(a) shows the sensed and measured 14 Volt input voltage of wind energy and sensed and measured voltage at the ADC0 is approximately 5 Volt. Fig. 5(b) shows the sensed and measured 14 Volt input voltage of solar energy and sensed and measured voltage at ADC1 is approximately 5 Volt. These results can be referred and validated from Fig. 1 in Section II.

ii. Condition 2: 12 < solar ≤ 14



(b)

Figure 5. (a) and (b) 12 < solar – wind ≤ 14.

Fig. 6 demonstrates condition 3 and 4 described in Table 1. The input voltages of $V_{solar-wind}$ is 10.08 Volt. This voltage is between 9 Volt < $V_{solar-wind}$ ≤ 12 Volt as defined in Table 1.

Fig. 6(a) shows the measured input voltage of wind energy is 10.08 Volt and sensed and measured ADC0 voltage is approximately 3.59 Volt. Referring to (4), calculated number of bits is 733 bits. And (2) calculates the wind input voltage which is equivalent to 10.02 Volt. The calculated voltage is approximately same as measured voltage at the voltage divider circuit.

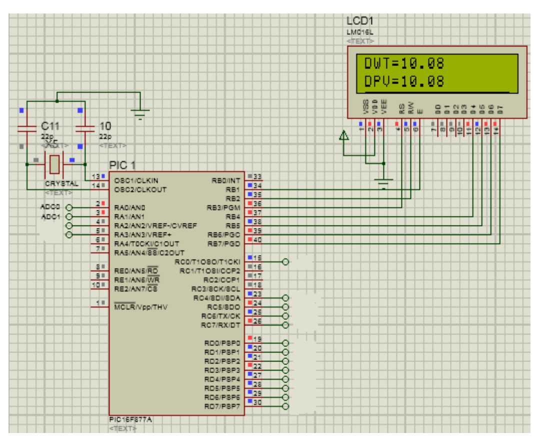
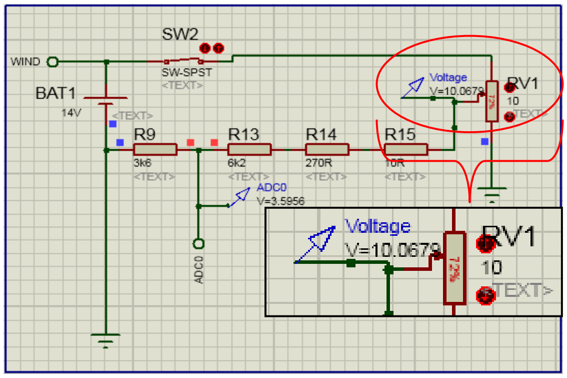


Figure 6. Solar – wind analogue voltage reading at 10.08 Volt.

i. Condition 3: 9 < wind ≤ 12



(a)

Figure 6. (a) Wind analogue voltage reading.

Fig. 7 demonstrates the condition 5 described in Table 1. During this condition, solar renewable energy source produces 6.43 Volt input voltage. In the following, the ADC1 calculation is used to validate the increment and decrement hierarchical voltage management and control strategy algorithm in Fig. 4 for $V_{solar-wind}$ to perform the voltage – base self – intervention technique.

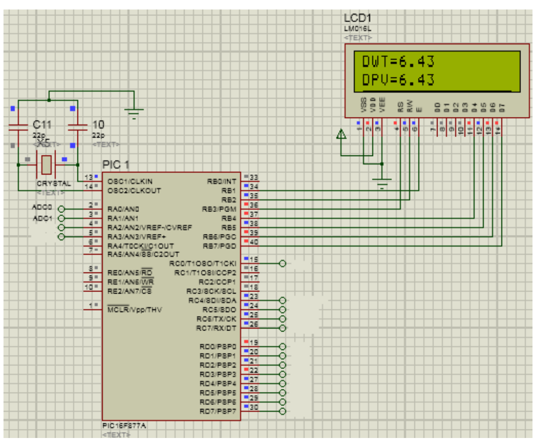


Figure 7. Solar – wind ADC voltage reading.

Hence, the number of bits is calculated using (2). Therefore, number of bits calculated is 470 bits and (4) calculates the ADC voltage which is 2.3 Volt. This can be verified using Fig. 7(a). ADC1 – solar renewable energy source input voltage is sensed and measured at 2.3 Volt. The sensed and measured ADC1 voltage is same as the calculated ADC1 voltage. This also shows that the voltage quantification can be used for $V_{solar-wind}$ to perform voltage – base self – intervention.

Fig. 8 shows the system goes into HALT MODE when the $V_{solar-wind}$ produces less than or equal to 5 Volt. During the HALT MODE, the system's overall performance is temporarily STOPPED.

Hence, the number of bits is calculated using (2). Number of bits calculated is 215 bits and (4) calculates the ADC voltage which is 1.05 Volt.

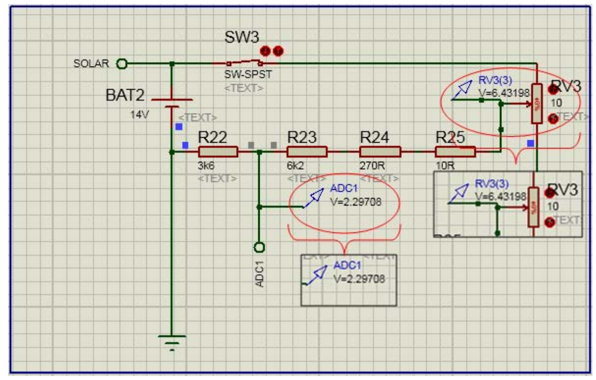


Figure 7. (a) Solar ADC1 voltage reading.

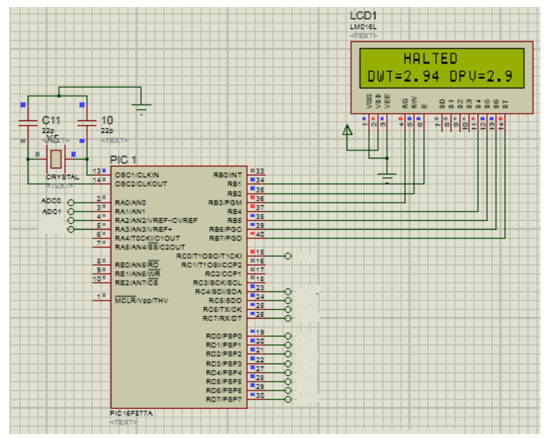
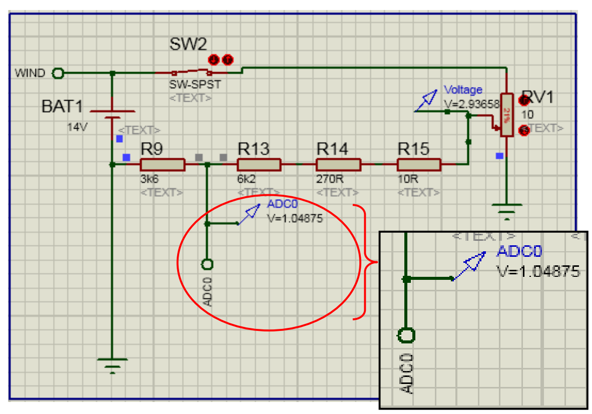
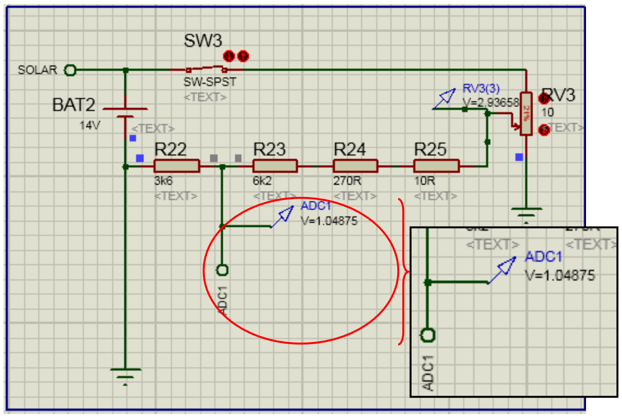


Figure 8. 0 < solar – wind ≤ 5.



(a)

Fig. 8(a) and (b) shows the measured input voltage, ADC0 and ADC1 of solar – wind renewable energy sources. Referring to Table 1 and Fig. 4, when the input voltage of the solar – wind renewable energy sources is less than 5 Volt, the increment and decrement hierarchical voltage management and control strategy algorithm will HALT the system. Hence, the calculation and simulation results validates that the increment and decrement hierarchical voltage management and control strategy algorithm managed to perform the system HALT condition when both input voltages are less than 5 Volt. This operation and system function is important because when the solar – wind renewable energy sources input voltage is low the overall system underperforms. This will cause inefficiency and ineffectiveness to the overall system operation.



(b)

Figure 8. (a) and (b) Solar – wind ADC Voltage Reading.

V. Conclusions

The research has successfully demonstrated the aims of using the voltage divider concept for voltage – base self – intervention technique. In addition, voltage quantification and the increment and decrement hierarchical voltage management and control strategy algorithm development also successfully demonstrated the voltage – base self – intervention for the solar – wind renewable energy sources.

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References

[1] R. Srinivasan, D. Ph, M. Yogaselvi, and R. Arulmozhiyal, “Standalone Hybrid Wind-Solar Power Generation System Applying Advanced Power,” *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 3, no. 2, 2014, pp. 627–636.

[2] S. M. J. Mary, S. R. Babu, and D. P. Winston, “Fuzzy Logic based Control of a Grid Connected Hybrid Renewable Energy Sources,” *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 3, no. 4, 2014, pp. 1043–1048.

[3] D. Shen, A. Izadian, and P. Liao, “A Hybrid Wind-Solar-Storage Energy Generation System Configuration and Control,” *2014 IEEE Energy Convers. Congr. Expo. ECCE 2014*, pp. 436–442.

[4] M. Engin, “Sizing and Simulation of PV-Wind Hybrid Power System,” *Int. J. Photoenergy*, 2013, Article ID 217526, 10 pages, http://dx.doi.org/10.1155/2013/217526 2013.

[5] J. B. V Subrahmanyam, P. Alluvada, K. Bhanupriya, and C. Shashidhar, “Renewable Energy Systems: Development and Perspectives of a Hybrid Solar-Wind System,” *Eng. Technol. Appl. Sci. Res.*, vol. 2, no. 1, 2012, pp. 177–181.

[6] A. Ali, S. Member, Y. Wang, W. Li, and X. He, “Implementation of Simple Moving Voltage Average Technique with Direct Control Incremental Conductance Method to Optimize the Efficiency of DC Microgrid,” in *2015 International Conference on Emerging Technologies (ICET)*, 2015, pp. 1 – 5.

[7] M. F. Almi, M. Arrouf, H. Belmili, S. Boulouma, and B. Bendib, “Energy Management of Wind / PV and Battery Hybrid System,” *Int. J. New Comput. Arch. their Appl.*, vol. 4, no. 1, 2014, pp. 30–38.

[8] K. Strunz, E. Abbasi, and D. N. Huu, “DC Microgrid for Wind and Solar Power Integration,” *Emerg. Sel. Top. Power Electron. IEEE J.*, vol. 2, no. 1, 2014, pp. 115–126.

[9] a Azizi, A. Salavati, H. Chalangar, and S. M. T. Bathaee, “Novel Control Method for Intermittent Renewable Source in DC Microgrid,” *Sci. Int.*, vol. 26, no. 1, 2014, pp. 211–216.

[10] S. D. Arco, R. Rizzo, and P. Tricoli, “Energy Management of Stand-Alone Power Systems with Renewable Energy Sources,” in *Proceeding of ICREPQ*, vol. 1, no. 1, 2006, pp. 1–7.

[11] B. V Aralakshmi and C. S. S. A. I. P. Rathyusha, “A Novel Control Strategy for Power Control and Management in AC / DC Micro Grid in Distribution,” *Int. J. Sci. Eng. Technol. Res.*, vol. 04, no. 23, 2015 pp. 4425–4431.

[12] N. Kamal and S. S. Kumar, “Hybrid Power Generation for Distributed Grid Applications Principal of Vivekananda College of Technology for Women , Tiruchengode , India,” *Middle-East J. Sci. Res.*, vol. 24, no. 1, 2016, pp. 51–58.

[13] J. Yu, C. Dou, and X. Li, “MAS-Based Energy Management Strategies for a Hybrid Energy Generation System,” *IEEE Trans. Ind. Electron.*, vol. 0046, no. 99, 10.2016, pp. 1–9, doi: 10.1109/TIE.2016.2524411.