Smart Solar Energy

Michaela Harrell, *REU Participant Student, Clark Atlanta University*

Prof. Brad Lehman, Prof. Mahshid Amirabadi, *Electrical and Computer Engineering, Northeastern University*

Jonathan Kim, Xinmin Zhang, Graduate, *Northeastern University*

Northeastern University College of Engineering

Abstract

DC arc faults can happen when a current passes through two electrical conductors of opposing charges with a short distance between each other combined with a high voltage. DC arc faults can be potentially dangerous when undetected. This research will involve methods of arc fault detection, data collection and various filtering techniques to detect and observe the behavior of an arc.

PV power forecasting is essential in solar energy as it makes it possible to utilize the sun's energy and convert it to electricity. In this research, SAM (System advisor model) will be utilized as a method to collect data and build a PV system,. Which in turn will result in a comparison of two PV systems: Fixed roof mount and 1 axis tracking system.

Introduction

Majority of electrical fires in residential homes are caused by AC Arc faults due to the difficulty in detecting them. DC Arc faults cause fires on rooftop PV systems of both residential and commercial buildings destroying numerous photovoltaic (PV) arrays annually. Sufficient protection is needed as DC power increases in automobiles.

PV Power forecasting is used by power grid operators for energy market participation, unit commitment analysis, determining reserve requirements, contingency analysis and energy storage dispatch. The use of SAM (System Advisor Model) was to build a PV system based on either electricity energy requirement or cost and profit analysis.

Experimental Setup

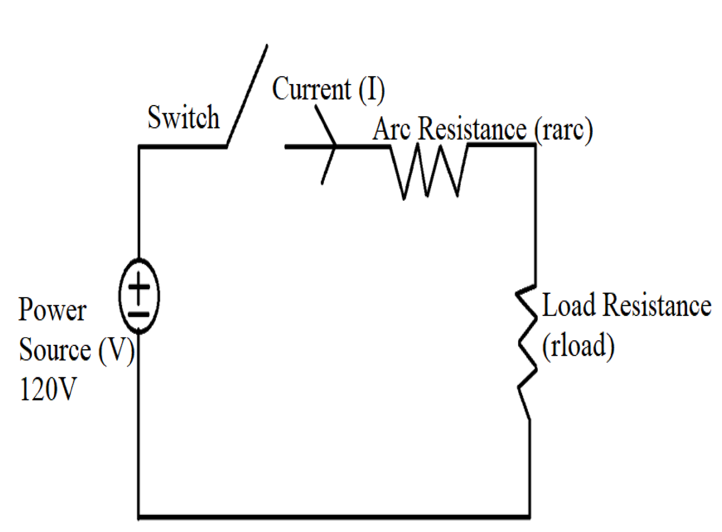

Figure 1. Microcontrollers and Data Acquisition Devices

Methods

Arc Fault Detection

- Data Collection: Microcontrollers and Data Acquisition Devices were paired with the MATLAB software to gather current data signals.
- Arc Fault Detection: Utilized MATLAB to input data collected from experiments and generate graphs to help analyze the statistical characteristics before and after the arc.

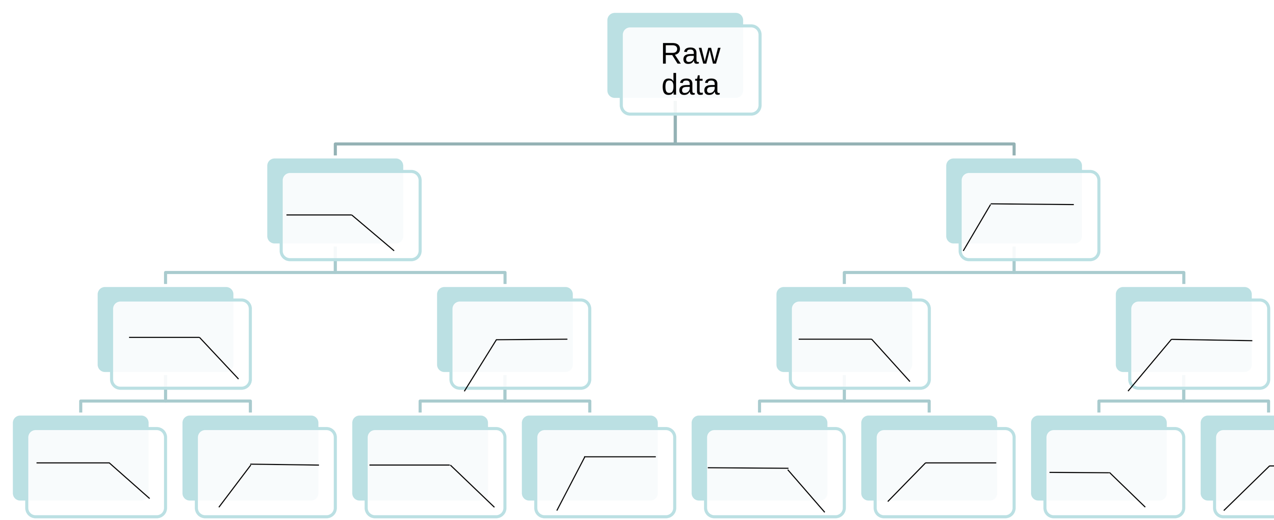

Figure 2. Discrete Wavelet Transform diagram

- Filtering Techniques: Fast Fourier Transforms and Discrete Wavelet Transforms were used to isolate certain arcing characteristics, such as the magnitude and variation of the current for targeted analysis.
- Discrete wavelet transform allows raw data to be passed through low-pass or high-pass filters
- Reached level 3 in statistical analysis using discrete wavelet transform

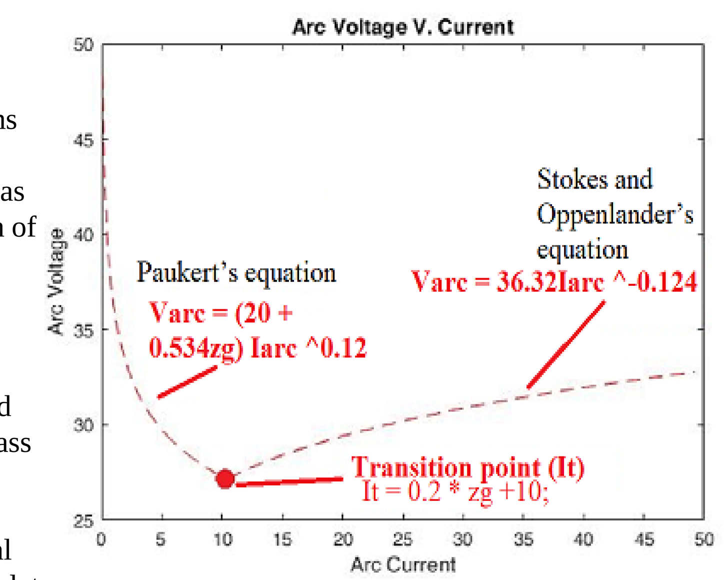

Figure 3. Transition arc.

- Stokes and Oppenlander's equation:
  Varc = 36.32Iarc ^-0.124
- Paukert's equation:
  Varc = (20 + 0.534zg) Iarc ^0.12
- Arc voltage decreases as the arc current increases
- After passing through the transition point the arc voltage gradually increases

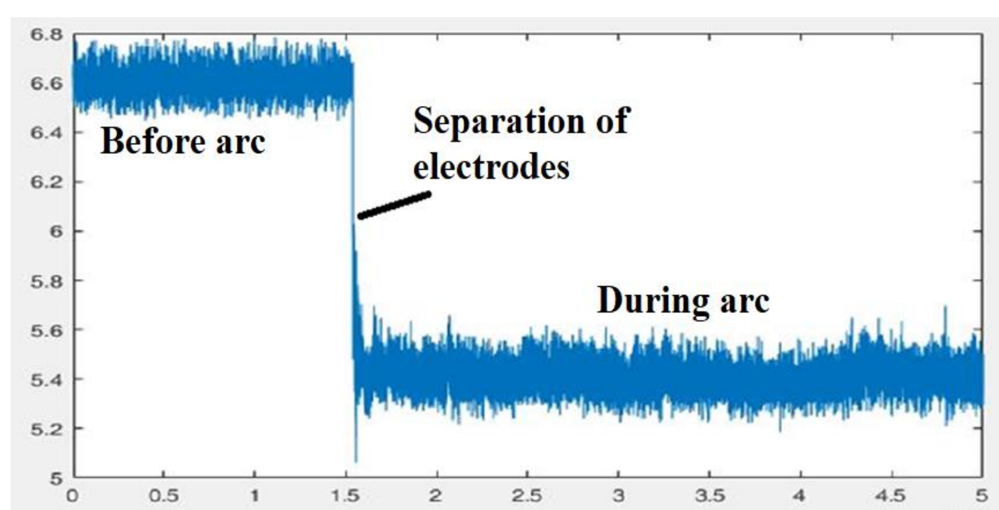

Figure 4. Raw data (0.5mm gap)

- 0.5mm electrode gap
- Before arc the current is constant
- The current immediately decreases after the arc is generated because the electrode gap is smaller
- The current remains constant during the arc

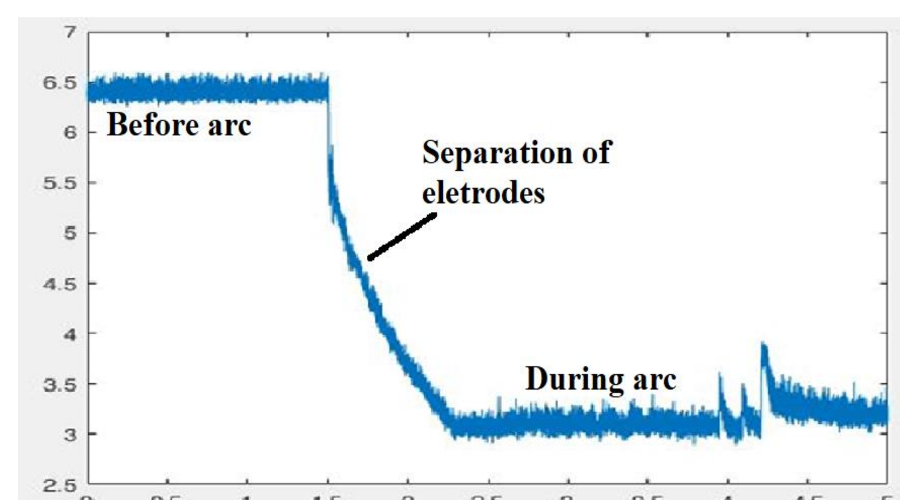

Figure 5. Raw data (5.0mm gap)

- 5mm electrode gap
- Before arc the current remains constant
- After generating the arc the current steadily decreases due to the large electrode gap
- The current continues at a constant rate lower than it started
- **Ohm's law (rearranged): R = V/I**
- The total resistance is seen increasing as the electrodes separate which causes the current to decrease
- Because the source voltage is constant, when the resistance increases due to the increase electrode gap distance, the total quotient decreases, thus decreasing the current as well.

Results

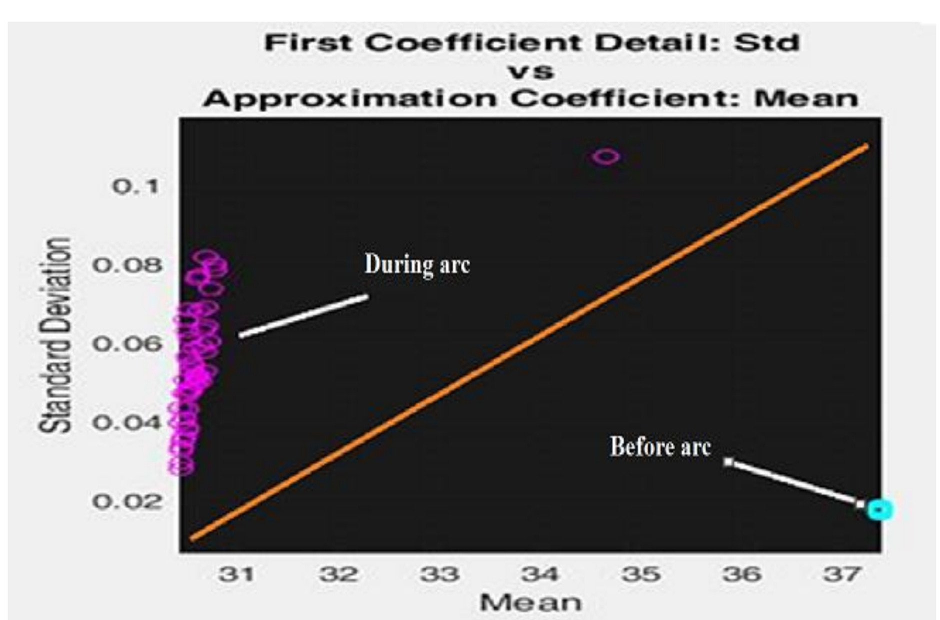

Figure 6. Statistical Analysis (0.5mm gap)

- Before the arc the mean is very high remains constant.
- The standard deviation is very low at this time.
- After the arc, the mean drastically decreases as the standard deviation fluctuates

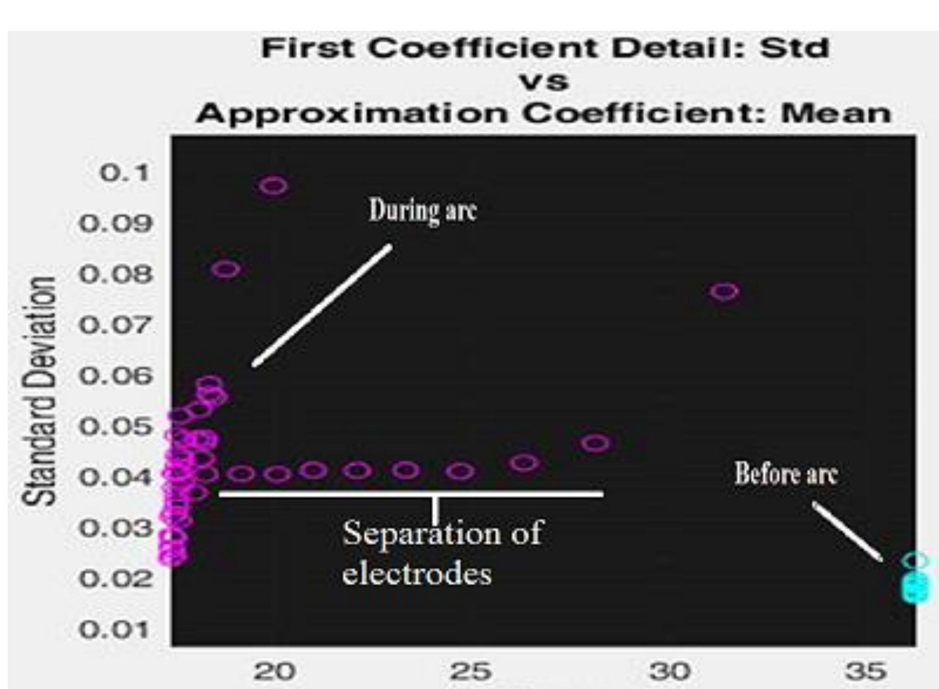

Figure 7. Statistical Analysis (5.00mm gap)

- The mean and standard deviation remain constant before the arc
- When the electrodes separate the mean then gradually decreases as the standard deviation increases then stays at a constant value, this is shown in the discrete wavelet transform as the current gradually decreases
- The standard deviation fluctuates as shown also in the discrete transform
- During the arc the standard deviation is still fairly high and the mean remains at a constant low value
- The standard deviation reaches a high peak a few times, but remains in a relatively lower range from then on.

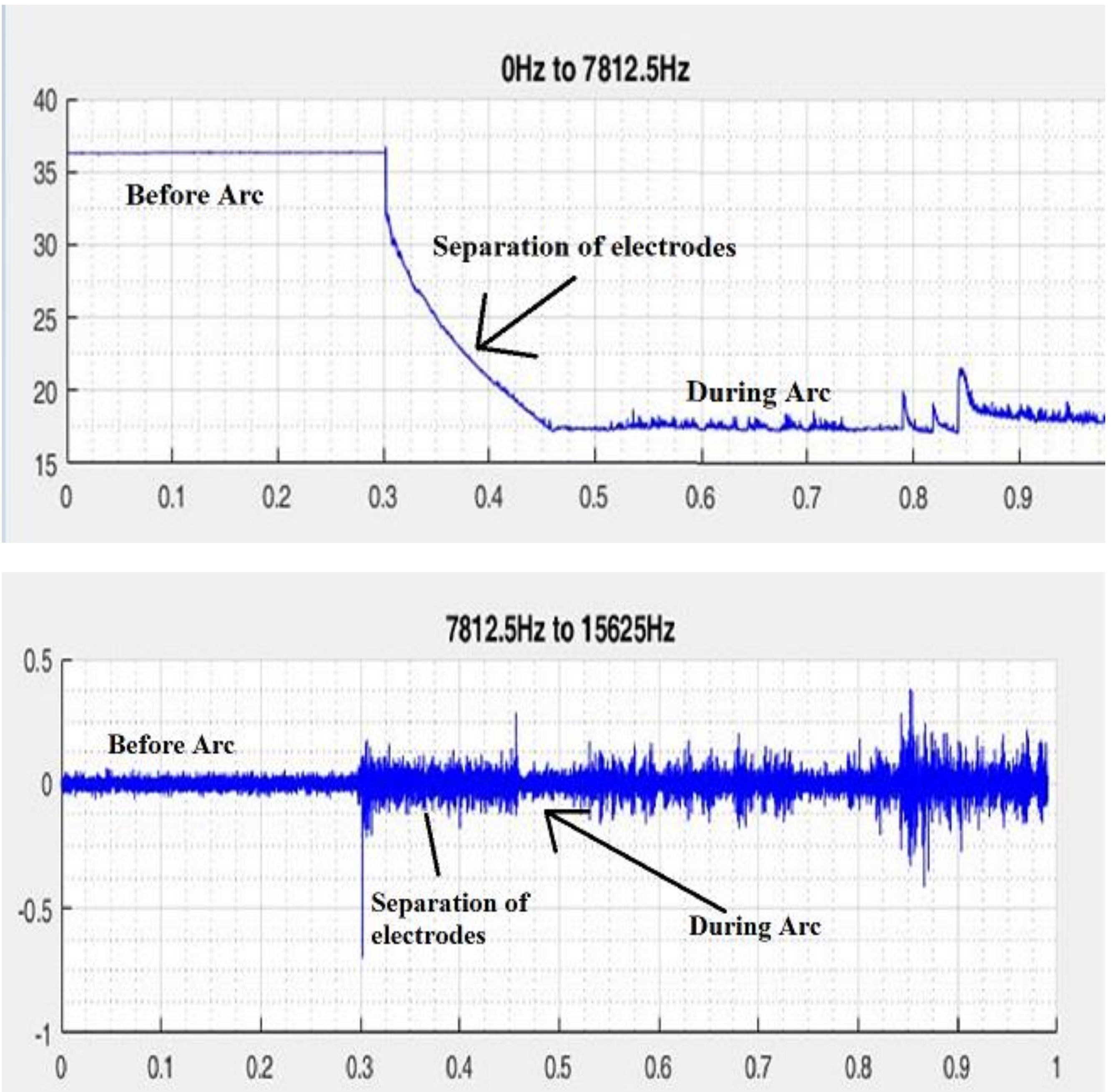

Figure 8. Discrete Wavelet Transform

Materials/Methods

PV Power Forecasting

Method/Tool : SAM (System Advisor Model)

SAM Procedure

Step 1: Location File
- Input longitude and latitude of specific location and automatically upload file

Step 2: System Design and Decide Array Type
- Adjust system parameters and select array type such as Fixed roof mount, 1 axis tracking, etc.

Step 3: System costs
- Compare two PV systems using tracker costs and sales tax percentage, cost estimated using SAM

Step 4: Lifetime of PV panel
- Lifetime = 25 years, cost at 25 years = total installed cost +Inverter cost (Year 15)+ Maintenance Cost

Step 5: Financial Parameters
- Calculate Federal CBI income, Federal ITC income, State ITC income

Step 6: Incentives
- Calculate total Costs at Year 25 (after incentives and credits) = Total Costs Year 25 (before incentives and credits) - Federal CBI - Federal ITC - State ITC

Step 7: Electricity rates using SAM
- (Calculate)Excess generation credit earned= Excess generation * Sell rate

Step 8: Electric load
- (Calculate) AC Power energy required per ear = (3000kWh*8)+ (3500kWh*4)

Results

Table I. Results comparison

	1 Axis Tracking PV System	Fixed Roof Mount PV System
DC Power Install Capacity	25.5kW	31.7kW
Initial installed cost	$90,280	$84,322
Total Costs Year 25 (after incentives and credits)	-$98,221	-$66,190.4
Payback Period	2.25068 years	1.7823 years

Conclusion

Arc Fault Detection

- The methods used in research have shown variations in current signals before and after the arc fault was generated.
- This shows that the arc fault has been successfully detected.

PV Power Forecasting

- PV system with 1 axis tracking is more efficient than fixed roof mount system because it needs a smaller installation capacity to produce the same required AC energy.
- However, fixed roof mount PV system installation and replacement cost during 25 years is lower. Therefore, it has a quick payback.

References

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