Smart Control of Buck Converters using a Switching-based Clustering Algorithm

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1 Abstract

- A new approach to the control of switching voltage regulators using a switching-based clustering algorithm.
- Also implemented a fuzzy-logic controller, proportional integral derivative controller, and a neural network based controller.

2 Introduction

- A buck converter takes an input voltage, and outputs a lower voltage.
- Applications include the power supplies of laptops and mobile phones as well as the power type and level conversion from solar panels.
- A comparison of the different controllers and a new, unsupervised machine learning controller which uses a switching-based clustering algorithm is presented

Figure 1: Application Areas of Buck Converters

- A conventional buck converter system consists of:
  - Two switches
  - A MOSFET
  - A diode
  - Resistor-inductor-capacitor elements

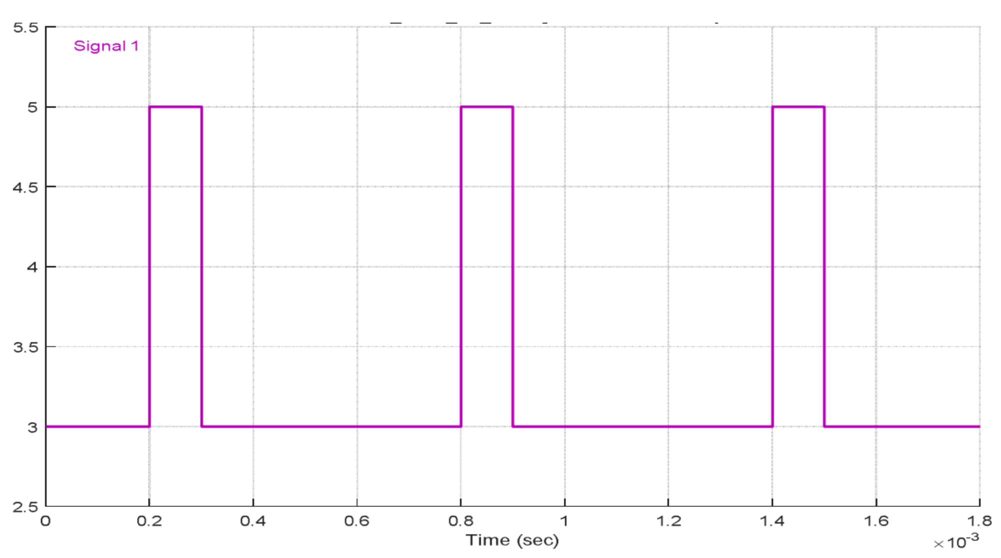

Figure 2: A pulsed reference voltage signal

3 Methods and Research Design

Switching Based Clustering

- The algorithm groups the output voltage into three clusters based on similarity
- Based on the clustering coefficients and indices, the switching frequencies of the PWM were adjusted.
- A new reference voltage signal was implemented.
- The purpose was to determine if the system is able to learn from the previous pulsed input and decrease the fall time to the desired output voltage.

Algorithm 1:Switching-based Clustering Algorithm

```
Input: Output Voltage (ç)
Output: Clustering Index (idx); Coefficient (y)
  voutData = vout.data;
  VoutMatrix =
  zeros(length(voutData),length(voutData));
  VoutTimeseries =
  zeros(size(vout,1),size(vout,1));
  for m = 1:length(voutData)
      VoutMatrix(m,:) = voutData;
  end
  VoutTimeseries = timeseries(VoutMatrix)
  function y = fcn(VoutTimeseries, vout)
  u2 = zeros(12,1)
  u2(1:11,1) = VoutTimeseries;
  u2(12,1) = vout;
  idx3 = kmeans(u2,3);
  idx = cluster(u2,3);
  y = idx3(12);
End
```

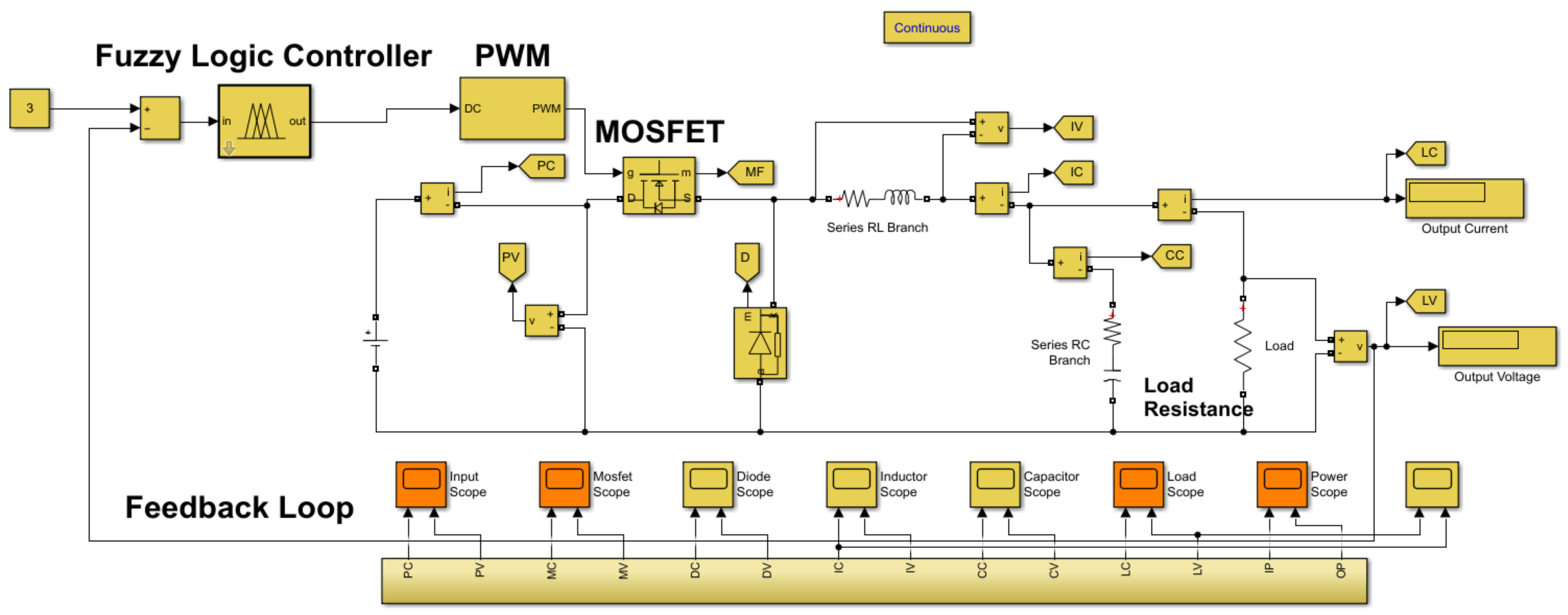

Figure 3: A model of the conventional controller with fuzzy logic control

4 Results

- A comparison of load voltages and currents of the original, PID, fuzzy logic, and switching-based clustering converter are shown in Figure 4.

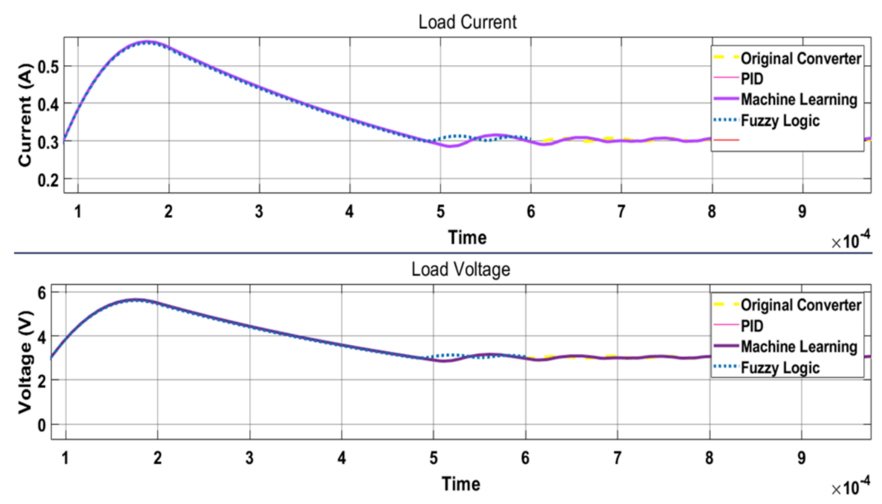

Figure 4: A comparison of the load currents and load voltages

- A comparison of load voltages and currents of the converter with the PID, fuzzy logic controller and switching-based clustering for the pulsed reference is shown in Figure 5.

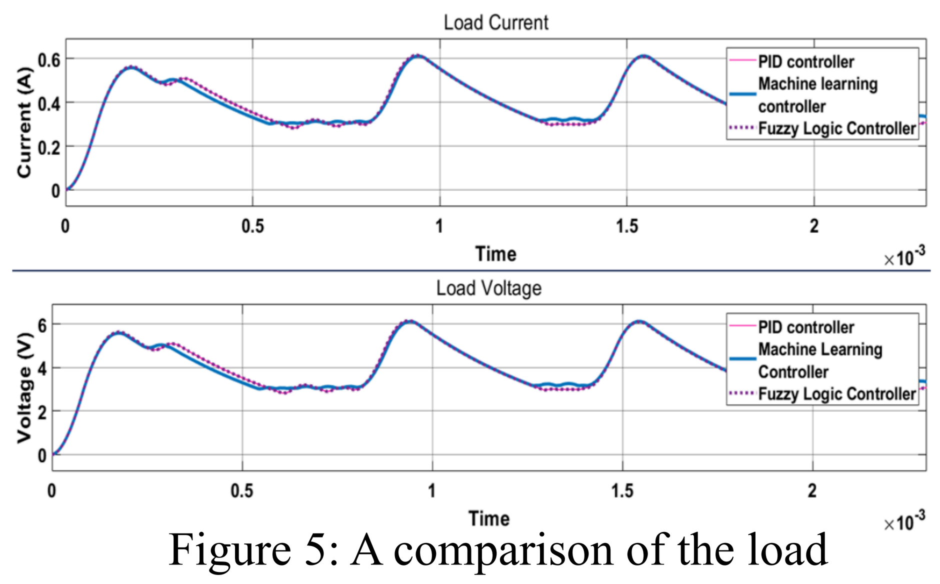

Figure 5: A comparison of the load currents and load voltages

	Controller and Values
Rise Time	Switching-based Clustering 1.75×10^{-4}s (fastest)
Fall Time	Switching-based Clustering 3.13×10^{-4}s (fastest)
Overshoot	Switching-based Clustering 2.58V (lowest)
Initial Value	Same value for all approaches
Peak Value	PID 5.64V (highest)
Final Value	Switching-based Clustering 3.01V (closest to 3V)

Table 1: Summary of Best Controllers for Initial Test

	Controller and Values
Rise Time	Fuzzy Controller 9.36×10^{-4}s (fastest)
Fall Time	PID 1.39×10^{-3}s (fastest)
Overshoot	Switching-based Clustering 2.94V (lowest)
Initial Value	Same value for all approaches
Peak Value	Fuzzy Controller 6.16V (highest)
Final Value	Fuzzy Controller 3V (closest to 3V)

Table 2: Summary of Best Controllers for Second Test

5 Conclusion

- The new switching-based clustering algorithm provided a stable voltage output more efficiently than competing methods.
- The proposed method could improve the performance of the system by 2.7% in terms of its settling time and by 0.6% in terms of the overshoot
- Future work could address implementing the controller for higher voltage and multi-level converter systems.

6 Acknowledgements

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7 References

B. W. Abegaz and M. Cmiel, "Smart Control of Buck Converters using a Switching-based Clustering Algorithm," 2019 14th Annual Conference System of Systems Engineering (SoSE), Anchorage, AK, USA, 2019, pp. 334-339.