[[1]](#footnote-1)

Integral-type second order sliding mode controller for power control\*

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*Abstract*— This paper

# INTRODUCTION

In many control applications,

# Preliminary

The goal of this section is to present parameter estimation.

# Design Methodology

Let us assume the general uncertain dynamical system

|  |  |
| --- | --- |
|  | (1) |

where is the state vector, is the vector of measurement, are the smooth nonlinear vector fields on and is a smooth function. In this equation, is the external disturbances and it is assumed that is bounded between two limits. The equilibrium point for this nonlinear system is supposed as , in which is the point of equilibrium. The aim of controller design is to determine a proper rule where the state output follows the reference signal . Therefore, the tracking can be obtained

|  |  |
| --- | --- |
|  | (2) |

To meet this objective, Integral-type second order sliding mode controller is proposed based on considering in the function of as output.

## A. First-order Integral-type sliding mode surface

Let us define the integral-type sliding mode surface

|  |  |
| --- | --- |
|  | (3) |

where , and are the PID-like positive gains for proportional, integral and differential error, respectively. In this equation, and are odd positive integer and is larger than . By this way, the tracking error is indicated in In Eq. 1, if it considered that and the input controller is defined as

|  |  |
| --- | --- |
|  | (4) |

Then, it can be shown that the integral-type sliding surface defined in (3) will converge to zero.

**Proof:** Let us consider the Lyapanov function as follows

|  |  |
| --- | --- |
|  | (5) |

Therefore, the first derivative of yields

|  |  |
| --- | --- |
|  | (6) |

In Eq. (6), it is required to compute . According to (3), the first derivative of (3) cab be obtained

|  |  |
| --- | --- |
|  | (7) |

By assuming , one can obtain from second-order derivation of Eq. (2) and replacing Eq. (1).

|  |  |
| --- | --- |
|  | (8) |

Consequently, using Eqs. (7), (8) and (6), can be calculated.

|  |  |
| --- | --- |
|  | (9) |

The above formulation demonstrates that when the error trajectory reaches the sliding surface (3), the signal of error will asymptotically converge to the origin. Due to the fact that the error is bounded, and the stability function is positive, the above proof shows that the Lyapunov function will converge to zero. According to continuity of the and convergency of it to zero, one can use Barbalat lemma and conclude . Consequently, we have

## B. Second-order Integral-type sliding mode surface

In this section, we want to introduce Second-order Integral-type sliding mode surface. In this approach, the algorithm is designed to force both and to zero. By this definition, the associated surface is proposed as follows

|  |  |
| --- | --- |
|  | (10) |

Where is a positive constant to make assure declination of . Differentiating of above surface (7), one obtains

|  |  |
| --- | --- |
|  | (11) |

Therefore, the condition of is the necessary condition for keeping the tracking error remained on zero. Consequently, one can obtain the same result as the characteristic of Eq. (9).

According to Eq. (11), it is required to compute and . The first and second-order derivatives of tracking error (2), we have

|  |  |
| --- | --- |
|  | (12) |
|  | (13) |

By replacing (12) and (13) in (11), one can find

|  |  |
| --- | --- |
|  | (14) |

The controller signal can be found, when the . It is necessary condition that can guarantee the error states converge to zero. The equivalent controller can be driven

|  |  |
| --- | --- |
|  | (15) |

This type of controller is second order controller, which can be reformed into two differential equations as follows where is the sub input of controller

|  |  |
| --- | --- |
|  | (16) |

There should be a switching controller to guarantee the switching surface converge to origin. The switching controller is defined as follows

|  |  |
| --- | --- |
|  | (17) |

Where and are positive, and . In this formula, makes the controller schema discontinuous, but because two integrations are performed, the final controller law is continuous and chattering free.

**Theorem 1:** Consider the general uncertain system (1) and the sliding surface (10). If we have as the control signal as follows

|  |  |
| --- | --- |
|  | (18) |

Where and are the equivalent and switching controllers computed by (16) and (17). Then, we can conclude that the integral-type sliding surface defined in (10) will converge to zero.

**Proof:** By replacing (16), (17) and (18) in (14), one has

|  |  |
| --- | --- |
|  | (19) |

Assuming the Lyapunov function is considered as follows

|  |  |
| --- | --- |
|  | (20) |

By considering , the first derivative of yields

|  |  |
| --- | --- |
|  | (21) |

Due to negativity of the first derivative of Lyapunov function and positivity of Lyapunov function, we can conclude that (21) the trajectory of error will converge to the origin and system is stable.

# Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes should appear before the acknowledgment.

Acknowledgment

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression, “One of us (R. B. G.) thanks . . .” Instead, try “R. B. G. thanks”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

References

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