ANALISIS RESPONS DINAMIS MOTOR *BRUSHLESS DIRECT CURRENT* (BLDC) DENGAN *SENSORLESS CONTROL* METODE KOMUTASI *FLUX THRESHOLD* UNTUK APLIKASI KENDARAAN LISTRIK RINGAN

TUGAS AKHIR

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Judul	Analisis Respons Dinamis Motor Brushless Direct Current (BLDC) Dengan Sensorless Control Metode Komutasi Flux Threshold Untuk Aplikasi Kendaraan Listrik Ringan	**Abdul Hadi Aldoreza**
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Abstrak

Kendaraan Listrik Ringan (LEV) membutuhkan sistem penggerak efisien dengan respons dinamis tinggi, namun sensor fisik pada motor *Brushless DC* (BLDC) rentan terhadap getaran dan lingkungan ekstrem. Penelitian ini mengimplementasikan *sensorless control* berbasis *Flux Threshold* via InstaSPIN-BLDC pada motor BLDC untuk mengevaluasi karakteristik respons dinamis, membandingkan tiga arsitektur kendali, serta menguji batas stabilitas kecepatan rendah dan redaman gangguan beban. Nilai ambang fluks yang didapat terbukti konsisten dan *speed-independent* pada rentang 500–2500 RPM tanpa kegagalan komutasi. Perbandingan menunjukkan Mode Kecepatan tercepat namun tanpa proteksi arus, Mode Arus berisiko *overspeed/stall*, sedangkan Mode Gabungan paling ideal dengan *steady-state error* dominan di bawah 2,6% sekaligus membatasi arus transien, meski *overshoot* mencapai 13,28% pada 500 RPM dan menurun ke 5,20% pada 2500 RPM. Batas operasi motor sangat dipengaruhi oleh *gain*: *gain* tinggi ($K_p = 3{,}0$; $K_i = 30$) terbatas di 420 RPM ($e_{ss} = 0{,}69\%$), *gain* optimal ($K_p = 1{,}0$; $K_i = 15$) berkinerja ideal pada 380 RPM ($e_{ss} = 0{,}39\%$), sedangkan *gain* rendah ($K_p = 0{,}50$; $K_i = 2$) mampu mencapai 310 RPM dengan penurunan akurasi ($e_{ss} = 1{,}61\%$).. Pada gangguan beban 4 A di lima titik kecepatan, *undershoot* tercatat 6,71–78,09 RPM dengan pemulihan hanya 0–0,30 detik. Metode *sensorless* berbasis fluks terbukti andal untuk LEV, meski memiliki keterbatasan pada kecepatan sangat rendah yang menyarankan topologi *hybrid* untuk penelitian lanjutan.

Kata Kunci: Motor BLDC, Kendaraan Listrik Ringan (LEV), *Sensorless Control*, *Metode Flux Threshold*, Respons Dinamis, InstaSPIN-BLDC.

Title	*Dynamic Response Analysis of a Brushless Direct Current (BLDC) Motor with Sensorless Control Using the Flux Threshold Commutation Method for Light Electric Vehicle Applications*	**Abdul Hadi Aldoreza**
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Abstract

Light Electric Vehicles (LEVs) require efficient drive systems with high dynamic responses, but physical sensors in Brushless DC (BLDC) motors are vulnerable to vibrations and extreme environments. This research implements Flux Threshold-based sensorless control via InstaSPIN-BLDC on a BLDC motor to evaluate dynamic response characteristics, compare three control architectures, and test low-speed stability limits as well as load disturbance rejection. The obtained flux threshold value proved to be consistent and speed-independent in the 500–2500 RPM range without commutation failure. The comparison indicates that Speed Mode is the fastest but lacks current protection, and Current Mode poses an overspeed or stall risk. Conversely, Combined Mode is the most ideal, maintaining a dominant steady-state error below 2.6% while simultaneously limiting transient current, although the overshoot reaches 13.28% at 500 RPM and decreases to 5.20% at 2500 RPM. The motor's operational limit is highly influenced by the gain: high gain ($K_p = 3.0$; $K_i = 30$) is limited to 420 RPM ($e_{ss} = 0.69\%$), optimal gain ($K_p = 1.0$; $K_i = 15$) performs ideally at 380 RPM ($e_{ss} = 0.39\%$), while low gain ($K_p = 0.50$; $K_i = 2$) can reach 310 RPM with reduced accuracy ($e_{ss} = 1.61\%$). Under a 4 A load disturbance at five speed points, the undershoot was recorded at 6.71–78.09 RPM with a recovery time of only 0–0.30 seconds. The flux-based sensorless method has proven to be reliable for LEVs, although it has limitations at very low speeds, suggesting a hybrid topology for future research.

Keywords: *BLDC Motor, Light Electric Vehicle (LEV), Sensorless Control, Metode Flux Threshold, Dynamic Response, InstaSPIN-BLDC.*