

Coast function parameters optimization for DC battery source inverter feeding three-phase inductive load

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ABSTRACT

The commonly reported measures of the predictive accuracy are evaluated in this paper. Absolute, squared, percentage, and integral errors methods are implemented, to reduce the objective function, which employed in model predictive control. These methods are usually investigated for dc source inverter, which controlled by finite set model predictive current control system, with three-phase induction motor load. In this paper, the evaluation includes different aspects, accuracy, complexity, system harmonics content, and execution time. A vital criterion in this process is the performance of the inverter, and the matching between the reference and the measured machine currents. The evaluation shows that for one term objective function, absolute and square errors give similar results with less execution time for the absolute error, but if multi terms objective function the square error is better.

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1. INTRODUCTION

The first thought of Model Predictive Control (MPC) and Retreating Horizon Control (REC) can be followed back to the 1960s when it was utilized as an intend to manage multivariable compelled control issues. The chemical and oil industrys, were pioneers in the appropriation of MPC, while the principal attempt to apply it to an electrical drive framework was made over two decades later [1-6]. Since for a two level voltage source inverter (VSI), there are eight mixes of inverter expresses, the wording of finite control set (FCS) is given. Moreover, the advancement of the inverter states is performed utilizing the retreating horizon control method, the center of model predictive control. The idea of MPC depends on the estimation of things to come conduct of the system, to use this data to find out ideal quantities for the inciting variables [7-10]. Execution of this method can be isolated into three principal steps: estimation of the factors that cannot be estimated, prediction of things to come conduct of the system, and system outputs optimization. Prescient control has many favorable circumstances that make it a genuine choice if high powerful control of electrical drives is required. The idea is straightforward and execute, also many system constraints can be added, multivariable cases can be considered, and nonlinearity can be incorporated [11]. This control strategy requires bunches of estimations contrasted with conventional methods. Despite that the prescient control plot depends on further developed control hypothesis, the subsequent control procedure is not any more mind-boggling than a traditional plan dependent on PI controllers and space vector modulation (SVM). Both control plans need a model of the inverter and the voltage vectors that it creates. In the old style plot, information on the voltage vectors is utilized for execution of the modulator. These voltage vectors are the limited arrangement (finite) of potential incitations in predictive control strategy. To alter the PI

controllers, linear equations representing the load model is required. The controller in the new strategy will compute the voltage vector next predictions. This can be accomplished by using a discrete-time version of the load model. The presentation of the PI controllers relies upon the suitable change of their parameters k_p and k_i [12]. This can be avoided in the new control strategy since no parameter's adjustment is needed. A cost capacity must be characterized, which on account of current control is extremely basic.

Intrigue additionally has expanded in figuring out which mathematical method will produce increasingly exact and exact predictions of the variables under control [13, 14]. Our motivation in this note is to investigate and decipher accessible factual proportions of the normal error related with a lot of model-delivered predictions. In this work an examination of the overall capacities of 1- average model performance error, 2-the square error (SE), 3- the absolute percentage error (APE), and 4- the absolute error (AE). Every one of these measures represents the error value in model variables for each prediction. These measures additionally have been utilized to appear the difference between the estimates to find which one is the most reliable.

Figuring of AE is generally basic. It includes adding the amounts of the absolute errors to get the total error value. Computing the SE is achieved by summing each square error. Every error value impacts the aggregate in relation to its square, instead of its amount. Enormous mistakes, as a result, affect the aggregate square error than do the littler errors. This implies that the complete square error will develop as the over all error is thought inside a diminishing number of progressively huge individual errors. The absolute percentage error (APE) is one of the most broadly utilized proportions of conjecture precision, because of its points of interest of scale-independency and interoperability. In addition, the integral for the absolute error (IAE) can be applied to compute the cost function, this function represents the system necessities by adding many small parts including with it. These parts are controlled variables reference following part that can be motor torque, speed or load current and voltage. As an example, for one variable the various methods of cost function (G) evaluation are:

$$G = |y_{reference}(k+1) - y_{predicted}(k+1)| \quad (1)$$

Where, $y_{reference}$ is the reference variable will not to be controlled while, $y_{predicted}$ is the predicted value for the same variable. The two parts are calculated at the instant of $(k+1)$ after discretizing the system model. The MSE and IAE are shown in equations (2) and (4).

$$G = (y_{reference}(k+1) - y_{predicted}(k+1))^2 \quad (2)$$

$$G = |y_{reference}(k+1) - y_{predicted}(k+1)| / |y_{predicted}(k+1)| \quad (3)$$

$$G = \int_0^{T_s} |y_{reference}(t) - y_{predicted}(t)| dt \quad (4)$$

Comparing equations 1 and 2, the last one produces large cost function for error values more than (1) while give a small results for errors less than (1). In power electronics, the first one will affect on the behavior of the controller sensitivity and much faster one is needed with high switching frequencies. While the second will reduce the sensitivity for small changes but with less reference tracking possibilities. For the (APE) as in equation (3) the huge detriment that it produces interminable or unclear qualities for zero or near zero values.

2. GENERAL DESCRIPTION OF DC BATTERY SOURCE INVERTER WITH THREE-PHASE INDUCTIVE LOAD

The standard form of the DC battery source inverter is exhibited in Figure 1 [15-25], which is familiar power electronics hardware utilized for driving three-phase inductive load. This device employs six IGBT switches (S_1 - S_6) and representing the load with L (inductance), R (resistance), and e (back e.m.f). The phase voltages V_{aN} , V_{bN} , and V_{cN} are the inverter output voltages. The real time model current in vector form can be obtained from:

$$v = R * i + L \frac{di}{dt} + emf \quad (5)$$

Note that for recreation and exploratory outcomes, the inductive load back-emf is thought to be constant sinusoidal waveform. The discrete form of the predicted load current derived from equation (5) for $(k+1)$ instant is:

$$i^{predicted}(k+1) = \left(1 - \frac{R \cdot T_s}{L}\right) i(k) + \frac{T_s}{L} \left(v(k) - \widehat{e.m.f}(k)\right) \quad (6)$$

The evaluated motor back e.m.f $\widehat{e.m.f}(k)$ can be found from the previous instant of time as:

$$\widehat{e.m.f}(k-1) = v(k-1) - \frac{L}{T_s} i(k) - \left(R - \frac{L}{T_s}\right) i(k-1) \quad (7)$$

Where, T_s is the sampling time, and $v(k)$ represents the voltage vector at time (k) which has seven values for this type of inverter. Each value is tested to calculate the predicted current at time $(k+1)$. The voltage vector that produce least cost function (less error); will be selected as a switching command to inverter switches.

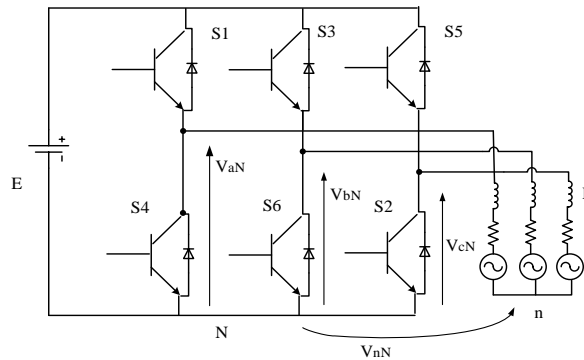


Figure 1. Topology of the DC battery source inverter.

3. ASSESSMENT MODEL PRECISION AND RESULTS

The simulation process for the inverter model is carried out using Matlab/Simulink. Finite (MPC) current control algorithm is applied to tracing the phase current references. The model parameters used are ($R=10\Omega$, $L=10\text{mH}$, $e.m.f=100\text{V}$, and $T_s=25\mu\text{sec.}$). For (AE) approach, figures (2) demonstrate the error between the reference current command and its relative actual one, while figure (3) shows the actual ϕ -a tracking its reference. Figures (4 & 5) exhibits the harmonics content for a selected window from the measured current and its distortion ratio for (AE) approach.

Figures (6-9) presents the same for (SE) approach, these results show that the model in the two approaches have nearly the same behavior. The percentage error (PE) approach when applied shows a slightly less error but with larger total harmonic distortion (THD) compared with the previous two approaches. This can be noticed in Figures (10-13).

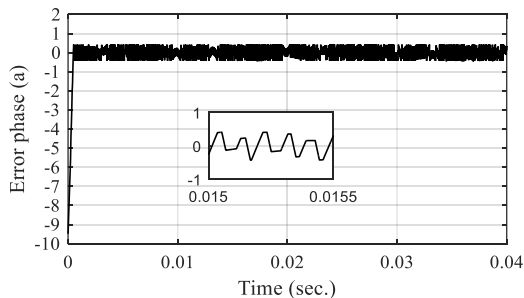


Figure 2. Error between the reference and actual current ϕ (a) (AE).

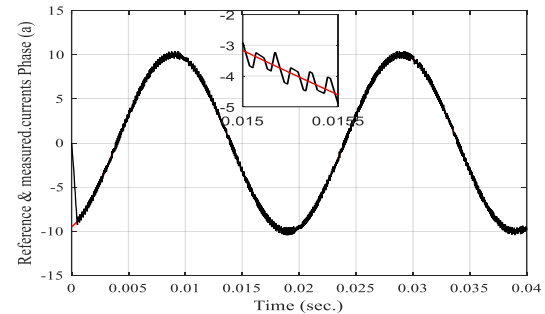


Figure 3. reference (red) and actual current ϕ (a) (AE)

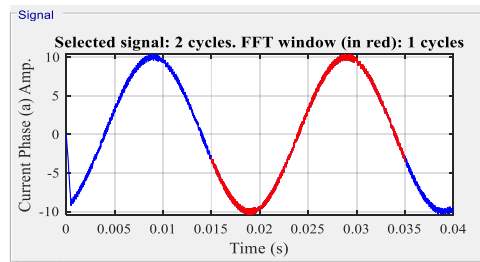


Figure 4. Selected current window for one cycle (AE).

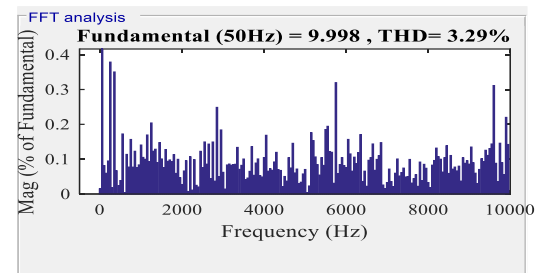


Figure 5. Harmonics content for the selected current

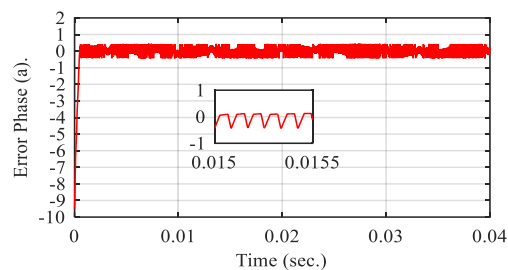


Figure 6. Error between the reference and actual current Ø (a) (SE).

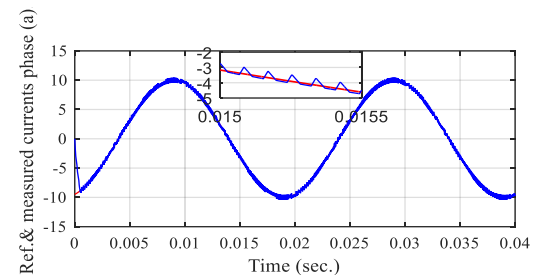


Figure 7. Reference (red) and actual current Ø (a) (SE)

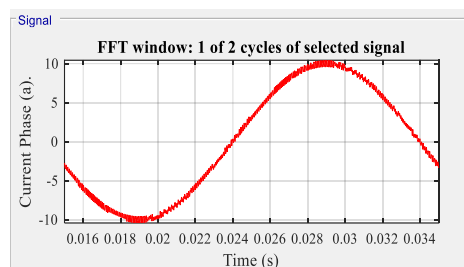


Figure 8. Selected current window for one cycle (SE)

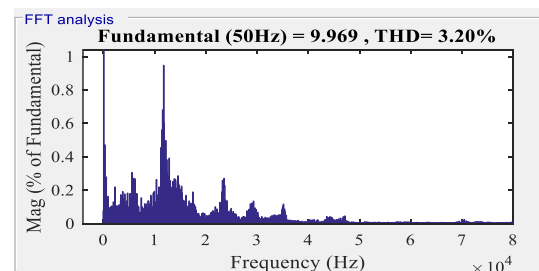


Figure 9. Harmonics content for the selected current

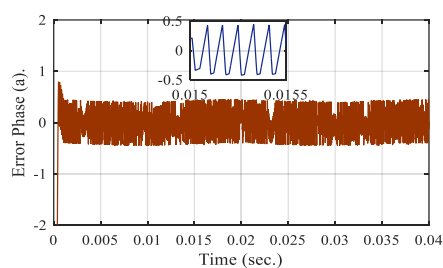


Figure 10. Error between the reference and actual current Ø (a) (PE).

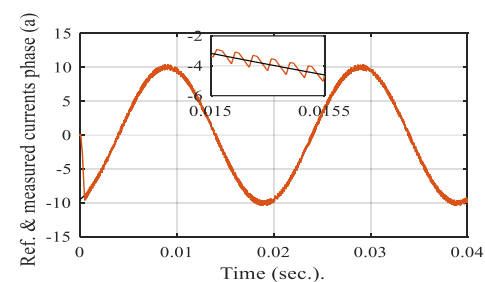


Figure 11. reference (red) and actual current Ø (a) (PE)

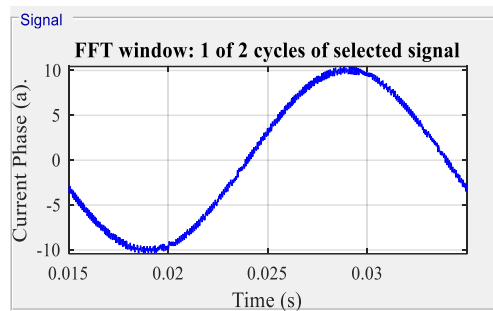


Figure 12. Selected current window for one cycle (PE)

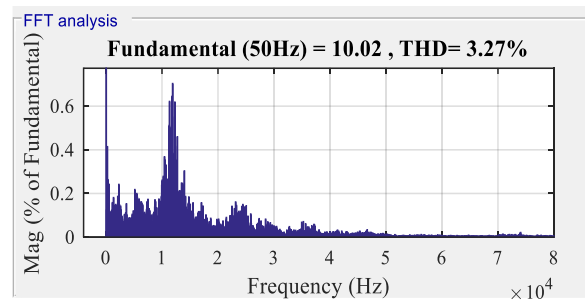


Figure 13. Harmonics content for the selected current

4. CONCLUSION

The aim of this work is to demonstrate and compare between various cost-function optimization approaches. The predictive control strategy (FCS-MPC) is used to drive inductive load via 3- ϕ battery source inverter. The analysis is carried out using Matlab/Simulink package, the approaches under consideration are absolute, square, and percentage error, while the integral error is eliminated because of its need for long execution time. The obtained results show that for (AE) and (SE) there was rapprochement between them in error amplitude, output current harmonics content and executing time, but in case of (AE) a faster and more sensitive for small error controller is needed. For the percentage error (PE) the error amplitude is slightly more than the previous two cases but there was a notable increase in harmonics content (THD). Since the deviations are squared, the SE gives a generally high weight to huge deviations. This implies the SE should be progressively valuable when enormous errors are especially unfortunate. One unmistakable favorable position of SE over AE is that SE keeps away from the utilization of taking the absolute for each error, which is unwanted in many numerical computing steps. The results approved the (FCS-MPC) performance quality, as can be seen in how the actual current tracks its reference command.

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