Direct Flux Vector Control of Induction Motor Drives in Maximum Efficiency Mode using Repetitive Control Technique

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ABSTRACT: In this paper, a misfortune limiting technique is proposed for acceptance engine rives to guarantee most extreme productivity operation for a given torque request and using repetitive controller. The proposed procedure straightforwardly directs the machine stator flux as indicated by the fancied torque, utilizing an ideal stator flux reference. Along these lines, the proposed methodology is reasonable for engine control plans that depend on direct flux control, for example, coordinate torque control or direct flux vector control. The maximum efficiency per torque (MEPT) stator flux guide is figured utilizing the customary no-load and short out tests' information. An iron misfortune show in light of the stator flux and recurrence is likewise proposed for the adjustment of the machine misfortune demonstrate and likewise for on-line checking of the iron misfortunes amid engine operation. The proposed MEPT methodology has been approved on a 2.2 kW enlistment machine and the engine proficiency has been measured for various speed qualities and variable load conditions. The trial comes about affirm the viability of the proposed arrangement. Also repetitive control technique is proposed in the scheme to improve flux torque characteristics.

KEY WORDS – Induction motor drives, direct flux vector control, repetitive control, loss minimization.

LIST OF SYMBOLS:

Aβ  
stator stationary reference frame  
(dm, qm)  
rotor mechanical frame  
(d, q)  
rotor flux frame  
(ds, qs)  
stator flux frame  
v, i, L  
voltage, current and flux-linkage vectors with subscripts describing frame of reference  
s, r, m  
as subscripts: stator, rotor and magnetizing  
Rs, Rr, Rfe  
stator, rotor and core-loss resistances  
edq, ife  
back emf and core-loss current component  
idq, id, iq  
current vector and its d, q components after core-loss component is subtracted.
\( L_s, L_m \) stator and magnetizing inductances [H]
\( L_{ls}, L_{lr} \) stator and rotor leakage inductances [H]
\( \alpha, k_r \) leakage factor and rotor coupling factor
\( \omega_m, s \) rotor mechanical speed [rad/s] and slip
\( \omega, \omega_S \) synchronous and slip frequencies [rad/s]
\( p, f \) pole pairs and frequency [Hz]
\( T \) torque [N·m]
\( P_j, P_{fe} \) copper and core losses [W]
\( P_{loss}, P_m \) total power losses and mechanical power [W]
\( N \) Efficiency

\( k_{Hy}, P_{Hy} \) Hysteresis power loss coefficient [A] and power [W]
\( k_{EC}, P_{EC} \) Eddy current power loss coefficient [A/V] and power [W]
\( X, n \) core material dependent coefficients
\( V, A \) volume [m³] and area [m²] of core
\( N, d \) number of turns and lamination thickness [m]
\( B \) magnetic flux density [T]
\( \rho \) specific resistivity of core material [Ω·m]

I. INTRODUCTION
The nonstop need of vitality sparing requires more proficient electrical drives. This goal is satisfied by utilizing more proficient electrical machines and by the substitution of steady speed drives with Adjustable Speed Drives (ASD) utilizing ideal control systems to completely abuse the electrical machines highlights. Because of its toughness, basic innovation, upkeep freeness and minimal effort, the Induction Machine (IM) still speaks to the significant vitality shopper in ASDs. The IM has solid contenders, for example, the Permanent Magnet (PM) engines, which display better productivity and higher torque thickness [1]. Be that as it may, the cost of uncommon earth magnets has generously ascended in the course of recent years, bringing about cost increment of PM engines. The expanding cost of PM engines has restored enthusiasm for IM use for electric vehicle applications [2]. The IM can at present be an aggressive require flux-debilitating. An exploratory review for IM misfortunes amid flux-debilitating operation is exhibited in [3]. All things considered, ideal control procedures are expected to enhance the IM drives' productivity underneath base speed, particularly at light loads.

The proficiency of IM drives can be enhanced by flux adjustment as indicated by the heap request. As detailed in [4], the flux adjustment should be possible through three classes of misfortune limiting techniques,
executed for scalar or vector control of acceptance engine drives. The main classification utilizes the control of a solitary engine variable, for example, the removal control figure [5, 6] or the slip recurrence [7-9]. While the slip recurrence control needs the engine parameters, the dislodging power figure control does not. What's more, the control calculate control is more powerful for mechanical applications, particularly for low-flow drives. Both arrangements are appropriate for scalar control or vector control that is typically executed with backhanded rotor field situated vector control utilizing current direction in rotor flux outline. An IM circuitous flux situated control conspire for electrical vehicles has been displayed in [10]. The reference streams for the present control are produced with a guide whose info is the required torque and working rate. The guide is acquired after an alignment procedure that incorporates torque estimation and a rotor time steady adjustment utilizing a warm model that utilizes the deliberate stator temperature.

The second classification of misfortune limiting systems is spoken to by the pursuit control, where the engine flux is iteratively adjusted to limit the info control. The arrangement displayed in [11] depends on direct estimation of the info control. Despite the fact that this arrangement does not require the engine parameters, the union is moderate and it is most certainly not appropriate for drives requiring moderately speedier flow. In instance of fast load increment, the engine may haul out.

At long last, the third classification of misfortune limiting systems depends on a misfortune model of the engine or potentially the influence converter. These arrangements are characteristically reasonable for vector control plans and they are the most reliant on the engine parameters. For instance, the strategy displayed in [6] utilizes backhanded rotor field arranged vector control in (d,q) rotor flux outline and alters the flux level to even out the misfortunes subject to the d-hub flux current part with the misfortunes that are subject to the q-hub torque creating part. The center misfortunes are figured utilizing an comparable center misfortune resistance, while the stray load misfortunes are not considered. A more expounded misfortune show that takes into account the PWM operation and the heap stray misfortunes is exhibited in [12] for pump applications. The ideal flux is created utilizing an Artificial Neural Network (ANN) controller; the productivity pick up has been completely illustrated, be that as it may, no analyses have been given to demonstrate the element execution if there should be an occurrence of load changes. Despite what might be expected, the arrangement introduced in [13] is centered around the element execution to limit the misfortunes amid torque homeless people. This arrangement is executed in rotor flux reference outline furthermore gives initial a model-based ideal rotor flux reference that limits misfortunes at consistent state for given torque and speed. At that point, an ideal flux variety is proposed amid torque drifters to get decreased misfortunes amid homeless people. Another misfortune limiting system is as of late proposed in [14] that uses port-controlled Hamilton hypothesis. The misfortunes are limited however with the presumption that the center misfortune resistance stays steady. Adequacy of the strategy through trial results is yet to be demonstrated. Systematic calculation of ideal d-pivot current reference choice is utilized for limiting center and copper misfortunes in [15].

The objective of this paper is to propose a Maximum Effectiveness per Torque (MEPT) procedure for acceptance engine drives working at variable burdens. The proposed technique employs the approach of controlling a solitary engine variable (stator flux) as do the misfortune limiting arrangements having a place with the in the first place class, however the ideal stator flux era is based on an engine misfortune demonstrate, making the proposed technique as a mix between the first and the third classifications of misfortune minimization techniques.

The proposed strategy is appropriate for control plans with direct stator flux direction, for example, Direct Torque Control (DTC) [16] or Coordinate Flux Vector Control (DFVC) [17]. The MEPT system utilizes an ideal stator flux reference and direct stator flux direction to get greatest engine effectiveness as indicated by a given torque request.

The proposed MEPT procedure speaks to a more non specific approach contrasted with the Maximum Torque per Ampere (MTPA) arrangement introduced in [18] with the go for limiting the copper misfortunes at decreased burdens. With deference to the characterization of the misfortune limiting techniques presented beforehand, the technique [18] can be incorporated into the main classification. Since the MTPA arrangement of [18] does not utilize a misfortune show, it doesn't naturally ensure the best engine effectiveness.
Not at all like the received system in [18], the new MEPT strategy likewise limits the center misfortunes at a given speed and flux level through an as of now built model.

The ideal MEPT stator flux reference is figured disconnected what's more, executed as Look-Up Tables (LUT) whose sources of info are the coveted torque and engine speed. The calculation of the ideal stator flux needs the engine information from ordinary no-heap and bolted rotor tests. An answer for the on-line estimation of iron misfortunes is likewise proposed for legitimate alignment of the engine misfortune demonstrate.

The proposed MEPT technique has been assessed on a 2.2 kW acceptance machine bolstered by a three-stage inverter. The engine effectiveness utilizing the proposed MEPT approach is contrasted and the efficiencies acquired for operation at steady appraised flux and for MTPA operation. The acquired comes about affirm the hypothetical investigation.

II. MODEL BASED LOSS MINIMIZATION

A. Acceptance Machine Model

The reference outlines utilized for machine demonstrating and control are characterized in Fig. 1 as takes after: stationary casing (α,β), rotor outline (d_m,q_m), rotor flux outline (d, q) and stator flux outline (d_s,q_s). As a general documentation, the machine stator vectors (voltage, flux, current) will be called \( \vec{v}, \vec{\lambda}, \) and \( \vec{I} \), furthermore, the subscript "s" will allude to the stator flux reference outline. The stator and rotor flux vectors are \( \vec{\lambda} \) and \( \vec{\lambda_r} \), separately.

The machine consistent state demonstrate utilized for the lossminimization methodology is characterized in the pivoting (d, q) rotor flux outline and the consistent state comparable circuit utilizing complex factors is appeared in Fig. 2.
In the unfaltering state proportional circuit, $s$ is the slip, $\sigma$ is the spillage figure, $L_s$ is the stator inductance, $L_m$ is the charging inductance, $L_r$ is the rotor inductance and $k_r = \frac{L_m}{L_r}$ is the rotor coupling variable. The Joule misfortunes are spoken to by the stator resistance $R_s$ and the rotor resistance $R_r$, while the center misfortunes are spoken to by the press misfortune resistance $R_f$ that is associated in parallel with the stator branch. For straightforwardness, the stray load misfortunes, the mechanical misfortunes and the extra misfortunes due to the inverter supply are ignored. Be that as it may, for the displaying of machine center misfortunes from no-heap test information, the mechanical misfortunes are dealt with to render the model precise.

The IM attractive model (current-to-flux relationship) is depicted as

$$
\bar{\lambda}_s = L_s \cdot \bar{i}_s + L_m \cdot \bar{i}_r = L_{ls} \cdot \bar{i}_s + L_m \cdot \bar{i}_m
$$

$$
\bar{\lambda}_r = L_m \cdot \bar{i}_s + L_r \cdot \bar{i}_r = L_{ms} \cdot \bar{i}_m + L_{ir} \cdot \bar{i}_r
$$

where $L_s$, $L_m$ are the stator and rotor spillage inductances individually, $\bar{\lambda}_s$ is the charging flux vector and $\bar{\lambda}_r$ is the charging current vector.

The immersion is represented in the attractive model by the variety of the polarizing inductance with the polarizing current. The stator and rotor spillage inductances are considered as constants at various polarization levels.

Expecting the unfaltering state operation, the relationship between stator flux and current vector segments, called attractive model, in ($d$, $q$) rotor flux edge is portrayed in (2), while the voltage condition is given in (3)

$$
\begin{align*}
\bar{i}_{sd} &= 0 \\
\bar{i}_{sq} &= -k_r \cdot \bar{i}_q \\
\lambda_{rd} &= L_m \cdot \bar{i}_d = \lambda_r \\
\lambda_{rq} &= 0 \\
\bar{v}_{dq} &= R_s \cdot \bar{i}_{dq} + \bar{e}_{dq} = R_s \cdot \bar{i}_{dq} + f \cdot \omega \cdot \bar{\lambda}
\end{align*}
$$

where

$$
\bar{i}_{d} = \bar{i}_{dq} + \bar{i}_{p} = \bar{i}_{dq} + \bar{e}_{dq} \cdot \frac{1}{R_s}
$$

In the unfaltering state proportional circuit, $s$ is the slip, $\sigma$ is the spillage figure, $L_s$ is the stator inductance, $L_m$ is the charging inductance, $L_r$ is the rotor inductance and $k_r = \frac{L_m}{L_r}$ is the rotor coupling variable. The Joule misfortunes are spoken to by the stator resistance $R_s$ and the rotor resistance $R_r$, while the center misfortunes are spoken to by the press misfortune resistance $R_f$ that is associated in parallel with the stator branch. For straightforwardness, the stray load misfortunes, the mechanical misfortunes and the extra misfortunes due to the inverter supply are ignored. Be that as it may, for the displaying of machine center misfortunes from no-heap test information, the mechanical misfortunes are dealt with to render the model precise.

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$$

$$
\bar{\lambda}_r = L_m \cdot \bar{i}_s + L_r \cdot \bar{i}_r = L_{ms} \cdot \bar{i}_m + L_{ir} \cdot \bar{i}_r
$$

where $L_s$, $L_m$ are the stator and rotor spillage inductances individually, $\bar{\lambda}_s$ is the charging flux vector and $\bar{\lambda}_r$ is the charging current vector.

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Expecting the unfaltering state operation, the relationship between stator flux and current vector segments, called attractive model, in ($d$, $q$) rotor flux edge is portrayed in (2), while the voltage condition is given in (3)
\[
\begin{align*}
\dot{I}_d &= 0 \\
\dot{I}_q &= -\frac{r_s}{L_r} \cdot \dot{I}_q \\
\lambda_d &= L_s \cdot \dot{I}_d \\
\lambda_q &= \sigma L_s \cdot \dot{I}_q \\
\lambda_{rd} &= \frac{L_m}{L_r} \cdot \dot{I}_d = \lambda_r \\
\lambda_{rq} &= 0 \\
\ddot{\omega}_m &= \frac{R_s}{L_s} \cdot \dot{I}_q + \ddot{\omega}_r = \frac{R_s}{L_r} \cdot \dot{I}_q + \ddot{\omega}_s \\
\end{align*}
\]  
(2)

\[
\begin{align*}
\tilde{I}_{dq} &= \tilde{I}_{dq} + \tilde{I}_s = \tilde{I}_{dq} + \frac{\tilde{U}_{dq}}{R_p} \\
\end{align*}
\]  
(3)

where 

The electromagnetic torque, the synchronous speed and the slip speed are defined in (4)-(6), respectively [19].

\[
T = \frac{3}{2} \cdot p \cdot (\lambda_d \cdot \dot{I}_q - \lambda_q \cdot \dot{I}_d) = \frac{3}{2} \cdot p \cdot (1 - \sigma) \cdot L_s \cdot \dot{I}_d \cdot \dot{I}_q \\
\Theta = \Theta_{m} + \Theta_{slip} = \Theta_{m} + s \cdot \Theta \\
\Theta_{slip} = \frac{\dot{I}_q}{\tau_r} \\
\]  
(4-6)

where \(p\) is the pole sets number, \(\tau_r = L_s / R_p\) is the rotor time steady, \(s\) is slip and \(\sigma = 1 - \sigma = Lm^2r^2 / R_r\) is the aggregate spillage consider. A vector graph at enduring state working conditions is appeared in Fig. 3; for effortlessness, the "dq" subscripts have been precluded for the vector documentation. As indicated by the attractive display (2), the stator current vector "idq forces the machine flux vector and the electromagnetic torque. The aggregate stator current idq incorporates likewise the iron misfortune part.

The polarizing current vector extent is close to the d-pivot part of the stator current vector downstream the iron misfortune resistance, i.e.

\[
|\tilde{I}_{m}| \approx |\tilde{I}_{dq}| \\
\]  
(7)

\[
\begin{align*}
\text{Figure 3. Vector diagram in rotor flux frame at steady state operation}
\end{align*}
\]

**B. Loss Model**

In the equal circuit appeared in Fig. 2 where the mechanical misfortunes, the stray load misfortunes and the extra misfortunes because of the inverter supply are disregarded, the machine misfortunes then incorporate just the stator and rotor Joule (ohmic) misfortunes and the iron misfortunes because of the central flux segments, as depicted by (8) and (9), separately.
With reference to Fig. 3, the machine effectiveness at unaltering state operation is

\[ \eta = \frac{\frac{3}{2} \cdot R_e \cdot |i_{dq}|^2 + \frac{3}{2} \cdot k_e^2 \cdot R_e \cdot \omega^2}{P_{j} + P_{fe}} \]  

(8)

Clearly any system that utilizes a model-based misfortune calculation must consider the engine temperature and the engine speed. What’s more, the variety of the iron misfortune resistance \( R_{fe} \) with the flux level must be assessed, as portrayed in the following segment.

### III. Demonstrating and Estimation of Iron Losses

The significant givers in the iron misfortunes are the hysteresis misfortunes and swirl current misfortunes. The misfortune due to attractive hysteresis (PHy) is characterized[20] as:

\[ P_{Hy} = \chi \cdot V \cdot f \cdot B_{\text{max}}^n \]  

(12)

where \( V \) is the aggregate center volume, \( f \) is the working recurrence, \( B_{\text{max}} \) is the pinnacle flux thickness achieved inside the center, while \( n \) and \( \eta \) are center material ward constants.

Clearly (12) requires the machine’s plan information and the properties of the attractive cover. Presenting a consistent \( k_{Hy} \) characterized by (13) with \( A \) being the region of attractive flux way and \( N \) being the quantity of winding turns, the geometric measurements related terms are lumped into this consistent. Utilizing \( k_{Hy} \), (12) can be changed to a more straightforward expression (14), which gives the hysteresis control misfortunes as an element of flux-linkage rather than attractive flux thickness. The flux linkage is an amount that can be effortlessly gotten from the deliberate electrical factors.

\[ k_{Hy} = \frac{\chi \cdot V}{N \cdot A} \]  

(13)

\[ P_{Hy} = k_{Hy} \cdot f \cdot A^n \]  

(14)

The exponent \( n \) ranges from 1.5 to 2.5 for commonly used core materials for electrical machines [20]. For instance, the non-oriented electrical steel material M400 65A produced by SurahammarsBruk AB has a constant \( n \) equal to 2.02 at 50Hz [21]. Similarly, the eddy current losses (PEC) in terms of machine’s geometric dimensions are given [20] by:

\[ P_{EC} = \frac{\pi \cdot d^2 \cdot f^2 \cdot B_{\text{max}}^2}{6 \cdot \rho} \]  

(15)

where \( d \) is the cover thickness, \( \rho \) is the particular resistivity of the attractive material. The expression (15) can likewise be improved to (16) by presenting a vortex current misfortune steady \( k_{EC} \) characterized by (17)

\[ k_{EC} = \frac{\pi \cdot d^2}{6 \cdot \rho \cdot N^2 \cdot A^2} \]  

(17)

\[ P_{EC} = k_{EC} \cdot f^2 \cdot \lambda^2 \]  

(16)

The aggregate iron misfortunes given by the entirety of (14) and (16) as communicated in (18) can likewise be resolved from the standard no-heap trial of the machine as endorsed by [22]. Under the test conditions suggested in this standard, the aggregate center misfortunes can be gotten as a component of connected voltage (and henceforth the flux). Once the aggregate center misfortunes are accessible, utilizing understood
numerical information fitting devices, the obscure parameters in (14) and (16) can be gotten. In any case, the standard no-load test gives the iron misfortunes at just a single recurrence (the test recurrence). Despite the fact that the iron misfortune show (18) can be built from information of a solitary no-load test at appraised recurrence, leading these tests at different frequencies gives a superior center misfortune display that can then be utilized as a part of movable speed acceptance engine drives.

\[ P_{Fe} = P_{Hy} + P_{EC} = k_{Hy} \cdot f \cdot \lambda^n + k_{EC} \cdot f^2 \cdot \lambda^2 \]  

(18)

No-load tests have been performed for the acceptance machine utilized as a part of the trial tests at five distinctive frequencies with variable voltage up to qualities that force a flux marginally over the evaluated esteem. The machine evaluated values also, parameters are given in the Appendix.

The iron misfortune coefficients \( k_{Hy} \), \( k_{EC} \) and the type term \( n \) are registered by considering the information of every one of the five tests. The got values for the machine under test are \( k_{Hy} = 1.591 \), \( k_{EC} = 0.0178 \), and \( n = 1.432 \). The center misfortunes at five unique frequencies as saw from the no-load tests are appeared in Fig. 4 for frequencies beneath the evaluated recurrence of 50 Hz. The misfortunes are contrasted and those gotten from the model (18) and a decent understanding is detailed in Fig. 4. In this way, (18) permits registering the iron misfortune resistance \( R_{fe} \) from Fig. 2 for given stator flux and recurrence. As an option, (18) may specifically supplant (9).

The iron misfortune demonstrate (18) can likewise be utilized for on-line estimation of iron misfortunes utilizing the assessed stator flux and engine recurrence.

![Figure 4. Experimental tests: IM iron losses as a function of flux at five different frequencies from 10 Hz up to 50 Hz; standard tests data compared with model (18).](image)

IV. MOST EXTREME EFFICIENCY PER TORQUE STATOR FLUX SHOW BASED COMPUTATION

Given a machine relentless state working point depicted by torque, mechanical speed and engine temperature, the objective of the proposed MEPT methodology is to acquire an ideal stator flux that relates to the most extreme engine effectiveness. The ideal stator flux \( \lambda_{MEPT} \) is figured disconnected utilizing an iterative PC based calculation methodology depicted beneath.

A. Required engine parameters

The required engine parameters are the machine inductances (\( L_{ls} \), \( L_{lr} \) and \( L_{m} \)), the machine stator and rotor resistances (\( R_s \), \( R_r \)) and the iron misfortune resistance \( R_{fe} \). The machine inductances and the resistances can be acquired from the ordinary no-load and bolted rotor tests alluded to a predetermined engine temperature. The
variety of the polarizing inductance with the charging current $L_m(i_m)$ must be known. With reference to Fig. 3 and condition (7), the charging current extent can be approximated with the $i_d$ current part. The most extreme polarizing current from the no-load test will be the most extreme permitted d-hub current $I_{d,max}$.

B. Current mapping in rotor flux edge and calculation of machine show

The system is fundamentally the same as the one portrayed in [18] what's more, needs as info the most extreme machine current $I_{max}$ as per the over-burden current point of confinement. The primary quadrant of the $(i_d, i_q)$ plane is mapped by methods for $m \times n$ current vector network, where a bland $i'(m,n)$ vector is portrayed as

$$i'(m,n) = I(m) \cdot e^{j\vartheta(n)} = i_d(m,n) + j \cdot i_q(m,n)$$

(15)

The stator current size traverses in the vicinity of zero and $I_{max}$, while the present position traverses between a base esteem and 90 electrical degrees, as appeared in Fig. 5.

---

**Figure 5. Mapping of $i'$ current vector in $(d,q)$ rotor flux frame**

The base esteem is not steady and it is decided to abstain from having a d-pivot current higher than $I_{d,max}$. Given the $i'(m,n)$ vector, the stator flux is acquired from the attractive show (2) in the wake of subtracting the spillage flux, where the polarizing inductance utilized by this model is registered as $L = f(i'(m,n))$, as indicated by (7), additionally allude to Fig. 6. In the event that the stator flux is known, the engine electromagnetic torque and engine slip speed can be figured with (4) and (6), separately. For a given working mechanical speed, the electrical speed is effortlessly processed with (5). At that point, the back-emf voltage, the aggregate stator current, the machine misfortunes and the effectiveness are processed utilizing (3) and (8)-(11) for guaranteed engine temperature.

C. Ideal stator flux calculation

For a given stator current extent $I(m)$, the $i'(m,n)$ current vector position $\vartheta(n)$ is fluctuated in the mapping region as indicated by the mapping method depicted previously. The ideal stator flux can be processed utilizing two methodologies:

a) Maximum Torque per Ampere (MTPA) approach:

This procedure was exhibited in [18] and chooses the flux $\lambda_{MTPA(m)}$ that compares to the most extreme torque. The MTPA flux does not rely on upon the engine temperature and speed, however just on the attractive model, i.e. the attractive immersion.

b) Maximum Efficiency per Torque (MEPT) approach:

The methodology chooses the flux $\lambda_{MEPT(m)}$ that relates to the most extreme effectiveness. For a given speed furthermore, stack torque, an ideal flux reference is registered that considers the center misfortunes at that flux level. By rehashing this method for all $m$ focuses between 0 also, $I_{max}$, a 1-by-m LUT can be acquired for either MTPA or the MEPT approaches. The MEPT flux relies on upon both engine temperature and engine speed. One conceivable arrangement is to rehash the MEPT calculation method for a few speed values and to construct a 2D-LUT legitimate for a predetermined temperature. For this situation, the MEPT flux is gotten as
an insertion as per the torque request and rotor speed. This work utilized torque-to-flux LUTs of 32 focuses (m=32) for a working pace. A few 2D-LUTs can be acquired for various engine temperatures.

D. Investigative outcomes
The MEPT ideal flux has been processed for a 2.2 kW acceptance machine whose parameters are accounted for in the Addendum. The polarizing inductance variety versus the crest charging current got from the no-heap test is appeared in Fig. 6. The greatest pinnacle polarizing current has been set at 6 A, the appraised stator polarizing current is \( d, \text{rated} \) is 3.5A. The MEPT operation utilizing the MEPT stator flux is contrasted and the operation at appraised flux in Figs. 7-9 for diverse speed values. An engine working temperature of 40°C is considered. Alluding to the iron misfortune models for different speed and flux levels introduced in Fig. 4, it is reasonable that the misfortunes are speed and flux-level reliant as found in Figs. 7-9.

V. SIMULATION RESULTS

![Figure 6. Simulation result waveform of Rotor speed, torque, stator current.](image1)

![Figure 7. Simulation result waveform of Rotor speed, torque, stator current with repetitive controller](image2)

![Figure 8. Simulation result waveform of torque vs rotor flux (with repetitive controller)](image3)
VI. Comparison of Simulation results.
Figures 6 and 7 show the simulation result waveforms of rotor speed, torque and currents without and with repetitive controller. Figures 8 and 9 show simulation result waveform of torque vs rotor flux without and with repetitive controller respectively. The results show the improvement in waveform with the use of repetitive controller.

VII. Conclusions
In this paper, a MEPT methodology is proposed for induction motor drives to guarantee greatest proficiency operation for a given torque request. The ideal flux calculation that yields MEPT operation considers the attractive immersion and prompts delineate two-dimensional LUTs whose information sources are the torque request and engine speed. The required engine parameters can be obtained from the standard no-heap and
bolted rotor tests. An iron misfortune demonstrate that predicts the iron misfortunes utilizing the stator flux and engine recurrence has additionally been proposed for legitimate MEPT adjustment and for on-line press misfortune estimation. Also simulation waveforms show the improvement after adopting repetitive controller in the control scheme.

The proposed MEPT procedure has been assessed on a 2.2 kW acceptance engine. The trial comes about demonstrate that the engine effectiveness is altogether enhanced beneath evaluated torque contrasted with the consistent appraised flux operation. With regard to the MTPA approach, the change is exceptionally little for engines having overwhelming Joule misfortunes, proposing that the MTPA approach is close ideal for such machines.

REFERENCES


