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Harmonic Reduction of PWM AC Chopper fed capacitor run induction motor using Evaporation based water cycle Algorithm

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***Abstract*—** This paper exhibits performance enhancement of PWM AC chopper fed capacitor run induction motor by using optimization algorithm. The PWM AC chopper utilizes improved pulse width modulation technique by incorporating three pulses in quarter cycle. The switching instants are obtained optimally by evaporation based water cycle algorithm. The power quality parameters considered in this paper are total harmonic distortion of current, total harmonic distortion of voltage, power factor and efficiency. The simulation result shows that proposed algorithm shows better performance compared to conventional sinusoidal pulse width modulation technique.

Keywords—optimization, ac chopper, harmonics, turn on instant, evaporation, streams

I. INTRODUCTION

Speed control of capacitor run induction motor is exhibited in domestic and industrial applications. The basic speed control technique is incorporated using variable resistor, but it has drawback of large power losses and more power dissipation. The integral cycle control gives promising control compared to variable resistance. The power losses and heat dissipation are less. The limitations of integral cycle control are poor power factor, harmonic distortions are more and unstable variations of speed. Hence the phase angle control shows better control compared to integral cycle control. The triggering angle is varied for different instants for different speed control. The ac voltage controller is placed in the main winding shows promising performance compared to auxiliary winding[1]. The placement of ac voltage controller in the auxiliary winding, at certain firing angles the variations causes unstable in nature. The performance of ac voltage controller is compared with single pulse width modulation technique. It is inferred that phase angle control shows better performance compared to single pulse width modulation technique[2]. The multiple pulse width modulation method gives enhanced operation compared to other techniques. The limitations of phase angle control are non-sinusoidal waveform, poor power factor at higher triggering angles and higher value of harmonic distortions. Hence one type of multiple pulse width modulation technique is called as sinusoidal pulse width modulation[3]. In this article the conventional controller sinusoidal pulse width modulation technique is compared with improved pulse width modulation technique incorporated by evaporation based water cycle algorithm. Improved pulse width modulation is a renowned technique for eliminating the harmonics in the output voltage. Different optimization methodologies are incorporated for capacitor run induction motor for enhancing the performance under different loading conditions. The genetic algorithm, particle swarm optimization, bee colony optimization, artificial neural networks, hybrid RGA–PS algorithms are used for implementing the asymmetrical pulse width modulation techniques[4,5]. In this paper section II consists of control of capacitor run induction motor, section III comprises of explanation of evaporation based water cycle algorithm, section IV specifies comparison of results between conventional and proposed system.

II. RELATED WORK

The permanent capacitor run induction motor has fixed capacitor for starting and running conditions. The starting toque is higher compared to centrifugal type single phase induction motor. The main application is focused on domestic fans utilized in industry and house hold applications. The fan load characteristic is enumerated as follows. The load torque for the fan type application is given as

$$T = K * \omega^2 \tag{1}$$

In sinusoidal pulse width modulation control, the performance enhancement of capacitor run induction is exhibited by using PWM AC chopper. This topology utilizes a set of combination with four diodes and main IGBT device. The load current flows through positive half and negative half cycle through the main switch S1.

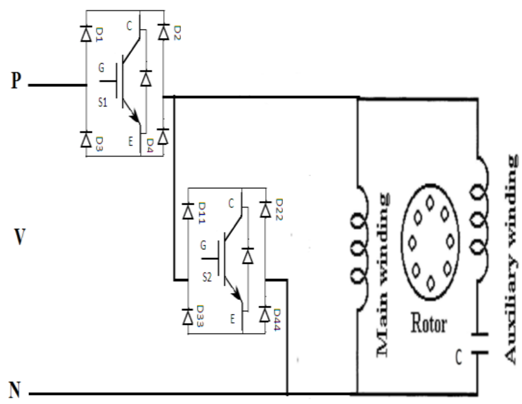

Figure 1. PWM AC chopper fed capacitor run induction motor

The motor load is inductive in nature hence a proper freewheeling action requires for dissipating the energy. Hence the power dissipation during positive half cycle and negative cycle is done through auxiliary switch S2. The triggering signal is to be generated for the main switch and freewheeling switch. For the period of positive half cycle, the current flows through diode D1, switch S1, diode D4 and connected to the capacitor run induction motor and return to the supply. For the period of negative half cycle, the current flows through capacitor run induction motor, diode D3, switch S1, diode D2 and connected supply voltage. For the period of positive half cycle, the freewheeling action takes through the path load, D3', switch S2, D2'and back to load. For the period of negative half cycle, the freewheeling action takes through the path load, D1', switch S2, D4'and back to load. In improved pulse width modulation control the pulses are of equal width and maintain full cycle symmetry. In improved pulse width modulation technique, the pulses are of different width and maintain quarter cycle symmetry. The switching on angles are varied while the switching off angles are fixed. The harmonics in the waveform is mathematically illustrated by Fourier series, the harmonic frequency component is separated using Fourier transforms. The harmonic elimination equation is non-linear and can be solved by numerical methods like Newton Raphson method[6]. The solution takes more iteration till it converges to reduced harmonic frequency components. Hence different optimization technique is evolved for solving these constraint problems.

III. METHODOLOGY

The harmonic elimination methods use different methods such as genetic algorithm, particle swarm optimization, bee colony optimization and artificial intelligence techniques [7,8]. The objective of the paper is to improve power quality parameters by maximizing power factor and efficiency and minimizing the total harmonic distortion of voltage and total harmonic distortion of current. This paper focusses on obtaining the optimal switching angles by evaporation based water cycle algorithm. Let the number of pulses be N. The switching instant for switching on the device is given as A1, A2 and A3 and switching off the device is given by B1, B2 and B3. The output voltage expressed in Fourier series is given as

$$V_o = \sqrt{2}V_i\left[C_o + \sum_{n=1}^{\infty}(C_n Sin(n\omega t) + C_n Cos(n\omega t))\right] \qquad (2)$$

Where n = 1,2,3…

By removing even components the output voltage can be written as

$$V_o = \sqrt{2}V_i\sum_{n=1}^{\infty}(C_n Sin(n\omega t) \qquad (3)$$

Where n =1,3,5….

The fundamental quantity C_1 is expressed as

$$C_1 = \frac{1}{\pi}\sum_{q=1}^{N}\left[B_q - A_q - \frac{Sin2B_q - Cos2A_q}{2}\right] \qquad (4)$$

The Harmonic quantity C_n is expressed as

$$C_n = \frac{1}{\pi}\sum_{q=1}^{N}\left[\begin{array}{c}\frac{Sin(n-1)B_q - Sin(n-1)A_q}{n-1} \\ -\frac{Sin(n+1)B_q - Sin(n+1)A_q}{n+1}\end{array}\right] \qquad (5)$$

Where n = 3,5,7…

The total harmonic distortion of output voltage and current is given as[9]

$$THD_v = \frac{\sqrt{\sum_{n=3}^{\infty}V_{on}^{\ 2}}}{V_1} \qquad (6)$$

$$THD_i = \frac{\sqrt{\sum_{n=3}^{\infty}I_{on}^2}}{I_1} \qquad (7)$$

The problem formulation is attained for the main objective is to minimizing the total harmonic distortion at the output. The optimum switching angles are required for the improved pulse width modulation of ac chopper. The objective function is specified as

$$\underset{A,B}{Min}\, G = \sqrt{\left[(C_1 - V_{ref})^2 + C_3^{\ 2} + C_5^{\ 2} + ..C_n^{\ 2}\right]} \qquad (8)$$

The constraint is specified for the objective function[10]

$$0 \le A_1 \le B_1 \le \phi \ldots\ldots \le A_N \le B_N \le B_{\max} \qquad (9)$$

Where Vref is the reference output voltage, N=3 is the number pulses in quarter cycle. A and B turn on and off switching instants. Bmax is maximum switching angle and the value is 90 degrees. Φ is the boundary switching angles, for each set of pulse the boundary is 30 degrees. The basic idea of evaporation based water cycle algorithm is based on flow of rivers, streams towards the sea for a recurring process. Suppose there is a rainfall in a particular area, initial population of streams is generated randomly. The best value of stream with minimum objective function is selected as sea[11]. The other values of streams directly flow into the rivers or sea. The water from stream is absorbed by the river or the sea. The amount of water transferred depends on different streams. For the minimum objective function flow of stream gives better solution compared to rivers then it can be exchanged for the accurate result. In this regard the river and sea is also exchanged for the best solution. The evaporation operator is introduced to avoid the premature convergence of objective function minimization. The process of evaporation occurs in the sea and it creates drizzle in the streams and rivers. Due to drizzle, new positions of streams and rivers are formed near the location of sea to ensure optimum solution. Hence the location of stream and river is modified to check for minimum objective function for a particular iteration. The algorithm steps are discussed below Step 1: choose the initial parameters of the search space, the variables are Nsr, dmax, Npop, iteration number, Pareto archive size. Step 2: choose initial random population size for streams, rivers and seas. Step 3: calculate the objective function for each stream. Step 4: obtain the solutions of the random initial population by saving in Pareto archive and calculate crowding distance for selecting the sea and rivers. Step 5: find the flow concentration of rivers and sea by using the governing equations for calculating the crowding values.

$$Obj_n = FF_n - FF_{Nsr+1} \quad n = 1,2,3\ldots,N_{sr} \tag{10}$$

$$NS_n = round\left\{\left|\frac{Obj_n}{\sum_{n=1}^{Nsr} Obj_n}\right| XN_{Streams}\right\} \quad n = 1,2,3\ldots,N_{sr} \tag{11}$$

Step 6: The new position streams may directly flow to sea and exchange the locations of sea with stream gives minimum objective function and the corresponding equation is

$$Y_{Stream}^{t+1} = Y_{Stream}^{t} + rand * C * (Y_{Sea}^{t} - Y_{Stream}^{t}) \tag{12}$$

Step 7: The new position streams flow into the rivers and exchange the locations of river with stream gives minimum objective function and the corresponding equation is

$$Y_{Stream}^{t+1} = Y_{Stream}^{t} + rand * C * (Y_{River}^{t} - Y_{Stream}^{t}) \tag{13}$$

Step 8: The new position river flow into the sea and exchange the locations of sea with river gives minimum objective function and the corresponding equation is

$$Y_{River}^{t+1} = Y_{River}^{t} + rand * C * (Y_{Sea}^{t} - Y_{River}^{t}) \tag{14}$$

The rand is the random values from zero to one. The value of C is $1 < C < 2$

Step 9: The raining process is started when the evaporation condition dmax is satisfied. Calculate the objective function and select the new location with minimum value. The higher values are eliminated and update in Pareto archive.

Step 10: Determine the crowding distance of each Pareto archive and eliminate the lower values. The new locations for sea and rivers are selected and check the convergence criterion otherwise go to step 6.

Table 1 Optimal switching angles

V	A1	B1	A2	B2	A3	B3
100	16.07	30	53.44	60	63.41	90
120	13.18	30	43.51	60	74.81	90
140	10.72	30	43.05	60	70.24	90
160	9.68	30	50.62	60	72.84	90
180	4.88	30	57.25	60	89.17	90
200	17.47	30	50.90	60	69.30	90

IV. RESULTS AND DISCUSSION

The evaporation based water cycle algorithm was computed by using MATLAB software. The parameters taken are listed below.
Population size: 50
Number of rivers and sea: 4
Evaporation condition constant: 1e-5
Maximum number of iterations: 100
The proposed improved pulse width modulation by evaporation based water cycle algorithm is compared with conventional sinusoidal pulse width modulation technique. The existing technique is compared with sinusoidal pulse width modulation technique and proposed evaporation based water cycle algorithm for the output voltage of 160V is shown in the table 2.

Table 2 Comparative analysis of different techniques

Method	%THDv	%THDi	Power factor
EWCA	1.02	0.75	0.84
SPWM	22.66	11.62	0.83

The convergence of the objective function is attained for different iterations. The result is obtained in 100 iterations. The objective function is minimized to a value of 0.418% and is shown in the figure 2. The performance enhancement parameters are total harmonic distortion, power factor and efficiency.

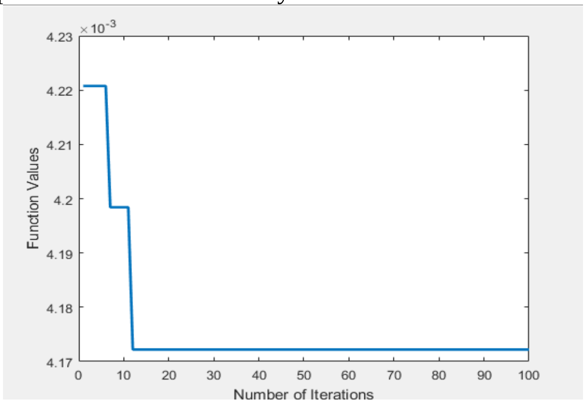

Figure 2. Convergence graph for different iterations

At 200V, the evaporation based water cycle algorithm has total harmonic distortions voltage of 1.02% while the sinusoidal pulse width modulation technique has 21.1%. The evaporation based water cycle algorithm technique has 20.08% lesser total harmonic distortion voltage compared to the sinusoidal pulse width modulation technique. Total harmonic distortion voltage is within the IEEE standard limit for the proposed technique leads to efficient operation of capacitor run induction motor under different loading conditions is shown in figure 3.

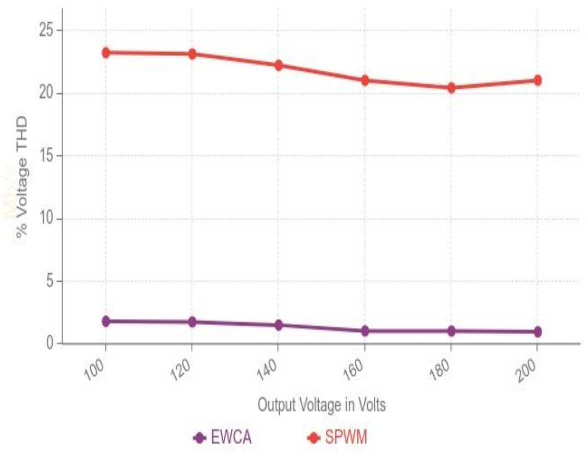

Figure 3. %THD voltage for proposed and conventional technique

At 200V, the evaporation based water cycle algorithm has total harmonic distortions current of 0.75% while the sinusoidal pulse width modulation technique has 11.5%. The evaporation based water cycle algorithm technique has 10.25% lesser compared to the sinusoidal pulse width modulation technique. Total harmonic distortion current is within the IEEE standard limit for the proposed technique. The lesser current harmonic distortion leads to minimal losses for the operation capacitor run induction motor is shown in figure 4.

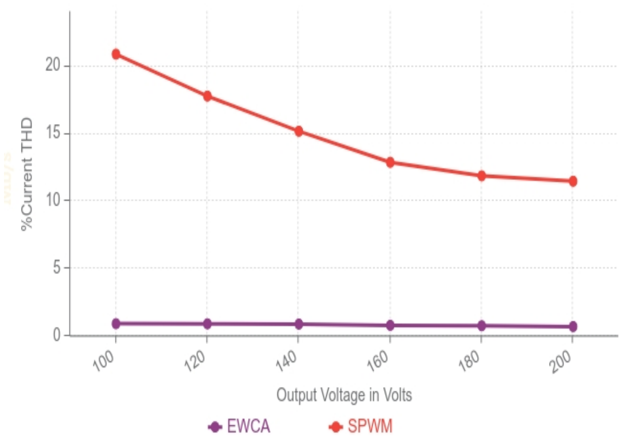

Figure 4. %THD current for proposed and conventional technique

At 200V, the evaporation based water cycle algorithm has power factor of 0.91 while the sinusoidal pulse width modulation technique has 0.83. It infers that the evaporation based water cycle algorithm technique has 0.08 more power factor compared to the sinusoidal pulse width modulation technique. The more power factor leads to distortion less operation capacitor run induction motor is shown in figure 5.

Figure 5. Power factor for proposed and conventional technique

At 200V, the evaporation based water cycle algorithm has power factor of 85% while the sinusoidal pulse width modulation technique has 79%. It infers that the evaporation based water cycle algorithm technique has 6% more efficiency compared to the sinusoidal pulse width modulation technique. It shows that proposed technique is better compared to conventional technique for the capacitor run induction motor is shown in figure 6.

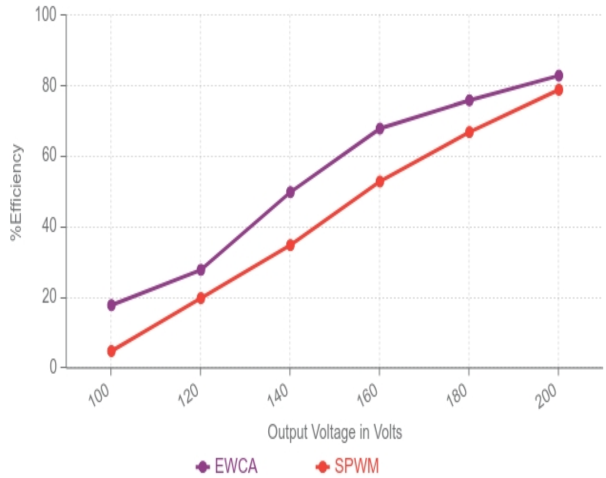

Figure 6. % Efficiency for proposed and conventional technique

V. CONCLUSION and Future Scope

This paper discusses novel optimization algorithm for the speed control of capacitor run induction motor with good power quality. The power quality parameters considered in this paper are efficiency, power factor, total harmonic distortion of voltage and current. At 200V, the evaporation based water cycle algorithm has total harmonic distortions voltage of 1.02% while the sinusoidal pulse width modulation technique has 21.1%. The evaporation based water cycle algorithm technique has 20.08% lesser total harmonic distortion voltage compared to the sinusoidal pulse width modulation technique. At 200V, the evaporation based water cycle algorithm has power factor of 85% while the sinusoidal pulse width modulation technique has 79%. It infers that the evaporation based water cycle algorithm technique has 6% more efficiency compared to the sinusoidal pulse width modulation technique. At 200V, the evaporation based water cycle algorithm has total harmonic distortions current of 0.75% while the sinusoidal pulse width modulation technique has 11.5%. The evaporation based water cycle algorithm technique has 10.25% lesser compared to the sinusoidal pulse width modulation technique. At 200V, the evaporation based water cycle algorithm has power factor of 0.91 while the sinusoidal pulse width modulation technique has 0.83. It infers that the evaporation based water cycle algorithm technique has 0.08 more power factor compared to the sinusoidal pulse width modulation technique. The controlling techniques implemented for PWM AC chopper are sinusoidal pulse width modulation and improved pulse width modulation by evaporation based water cycle optimization algorithm. The simulation results show that power quality improvement by proposed technique is better compared to conventional technique. This work can be compared with the other techniques like particle swarm optimization, cuckoo search optimization and proposed technique for the improved pulse width modulation for capacitor run induction motor.

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