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Classical Vs. Intelligence Controller in Resistance Spot Welding System

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Abstract**: *This paper is an attempt to accomplish a performance analysis of the classical (Proportional Integral) and intelligence(Artificial Neuro Fuzzy Inference System) control techniques on current spike reduction by means of magnetization level control in the primary winding on the medium recurrence transformer based DC spot welding framework. Cause for occurrence of spike in the primary winding of a transformer is unequal resistance between two secondary circuit's of the transformer and different characteristics of rectifier diode. Which leads to the magnetic saturation in the form of spikes in the primary current of a transformer Consequently over current protection switch off. So, Current Spike decrease is a significant factor to be considered while spot welding frameworks are concerned. This can be used in automobile industry and it is a major issue in spot welding system. The present control strategy is a piecewise straight control system that is enlivened from the DC-DC converter control calculations to enlist a novel current spike decrease technique in the MFDC spot welding applications. The traditional and insight controllers were utilized for spike decrease in essential current of welding transformer so as to make the opposition spot welding framework to work easily. Current control techniques by the above mentioned controllers are evaluated in terms total harmonic distortion (THD), Percentage of current spike reduction, percentage ripple in welding current, rise time and settling time. Matlab/Simulink^{TM} software is carried out for the analyzing the classical and intelligence controllers and results are tabulated.***

Index Terms ***: Spot Welding, Welding Transformer, Core Saturation, PI Controller And Intelligent Controller***

I. INTRODUCTION

Spot welding is popularly used metal joining process in automobile industry. While in the metal joining process, resistance of the secondary circuit of welding transformer is varying. this variation in the resistances and different characteristics of the rectifier diodes lead the magnetic core to become saturated. this introduces the spikes the primary current signal of the transformer[1]. An Artificial Neural Network(ANN) based implementation of the magnetization level detection in MFDC RSWS is introduced in [2]. The literature [2] discusses about the detection of the magnetization level by means of sensing and analyzing the primary winding current of the MFDC transformer.

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The choice of MFDC spot welding systems comes from the idea that if MFDC is powered from a three phase supply it would consume the current equally from all the phases thus reducing the chances of introduction of harmonic current. The occurrence of the current spike is unavoidable in any spot welding systems but MFDC has a history of producing lesser current spike. The dynamic characteristics of the spot welding machine is extracted by detecting the current and the voltage from the welding systems in order to provide a higher performance welding machines with completely optimized parameters for better working of the welding machines[3]. Appropriate A/D converter and the D/A converters are cast-off for the implementation of the automated welding machines [3].

This paper is an attempt to compensate on the spike that occurs in the primary transformer current due to the variation in the resistance in the two secondary windings of the transformer. An attempt in this paper is concentrated on the current spike that occurs at the transformer current wave. The mathematical model of the system is as defined in the literature [4] but the single-phase inverter is considered to be supplied from the DC source directly instead of the combination of the three-phase supply and the rectifier. A current controlled control strategy is developed in order to reduce the current spike occurring in the transformer primary current.

II. DYNAMIC MODEL OF RSWS

Thedynamic model of MFDC RSWS setup is shown in the Figure 1. which comprises of the input rectifier connected to the single phase inverter followed by the transformer with the rectifier at output side.

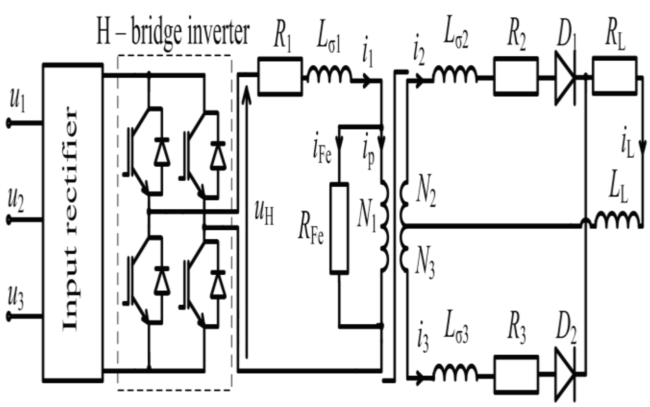

Figure 1. Dynamic model of RSWS

The demonstrating of RSWS arrangement has been examined in the writing [4].The circuit model as appeared in the Figure 1, contains rectifier yield UDC pursued by the single-stage inverter with the switches S1,S2, S3 and S4.

The yield voltage with 1000Hz of the inverter is provided to the welding transformer working with 1000Hz. $L\sigma 1$ is te spillage reactance of the essential winding, ,$L\sigma 2$ and $L\sigma 3$ are the spillage reactance of the two auxiliary windings. The welding transformer is an inside tapped and most generally utilized for the correcting circuit.

N1 is the quantity of turns in the essential, N2 and N3 are the quantity of turns in two auxiliary winding circuits individually. D1 and D2 are the rectifier diodes at the yield to get a DC control at the heap. Event of spikes in the essential current of the transformer is because of the inconsistent opposition happening in the two circuits $L\sigma 2$, R2, D1 and $L\sigma 3$, R3, D2 with RL and LL. generally happening for both the circuits is unavoidable. Therefore the remedial measures are fused that would diminish the spike in the essential current of a transformer.

Hysteresis controller is actualized to make the PWM procedure which would control the immersion [4] of the center subsequently it can diminish the spike in the essential current of a welding transformer. This control is additionally a conventional control, wherein the blunder in the real present and reference current is changed over in to the PWM age, which would help in accomplishing the present that is taken as the reference. So as to lessen the spike in the current, scientific model of the RSWS has been utilized to execute the proposed novel current control strategy.

The dynamic model of the RSWS [5]was developed dependent on the schematic introduction .In this work the model is worked with the program matlab\simulink dependent on the accompanying arrangement of conditions (1)- (9).

$$UH = R_1 i_1 + L_{\sigma 1}\left(\frac{di_1}{dt}\right) + N_1\left(\frac{d\varphi}{dt}\right) \quad (1)$$

$$0 = R_2 i_2 + L_{\sigma 2}\left(\frac{di_2}{dt}\right) + N_2\left(\frac{d\varphi}{dt}\right) + dip_1 + R_L i_L + L_L\left(\frac{d(i_2+i_3)}{dt}\right) \quad (2)$$

$$0 = R_3 i_3 + L_{\sigma 3}\left(\frac{di_3}{dt}\right) - N_3\left(\frac{d_\varphi}{dt}\right) + dip_2 + R_L i_L + L_L\left(\frac{d(i_2+i_3)}{dt}\right) \quad (3)$$

$$N_1 i_p + N_2 i_2 - N_3 i_3 = H(B) l_{ic} + \frac{2\delta B}{\mu_0} \quad (4)$$

$$i_L = i_2 + i_3 \quad (5)$$

$$i_1 = i_{Fe} + i_p \quad (6)$$

$$i_{Fe} = \frac{N_1\left(\frac{d\varphi}{dt}\right)}{R_{Fe}} \quad (7)$$

$$\varphi = B A_{Fe} \quad (8)$$

$$\Theta = N_1 i_1 + N_2 i_2 - N_3 i_3 \quad (9)$$

The Matlab model is a commitment of the [6] and accordingly it is reused in this work for a present control system utilized in this paper. The general square chart of the proposed Control framework appeared in Figure 2. Information of spike recognition is handled [7] to controller.

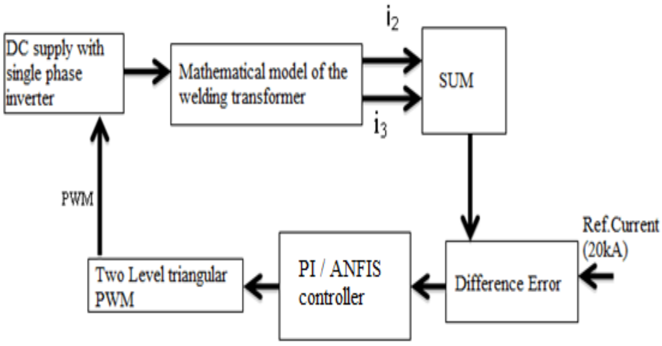

Figure 2. Block Diagram of Controllers for current spike reduction.

Implementation of proposed current controlled technique to control the spike in the primary current of welding transformer has shown in figure 2. The i_2 and i_3 are transformer secondary circuit currents [9] are added and sum of the currents is given to the comparator and this comparator is also having reference current as another input.

Comparator is check the actual current and reference current and then difference in current as error current will be given as input to the proportional integral controller which produce modulation index such that the saturation current equals the reference current.

Here analyzing the performance characteristics of classical (PI) versus intelligence controller (ANFIS) by considering total harmonic distortion, spike reduction capability, reduction in ripple content, rise time and settling time.

III. DESIGN OF CONTROL SYSTEM

A. PI Controller

PI controller is a criticism controller which drives the plant to be controlled [8] with a weighted entirety of the mistake (distinction between the yield and wanted set-point) and the basic of that worth. This control have relative addition which creates a yield corresponding to the info mistake and an essential increase to make the blunder zero for a stage change in the information.

Output of the proportional integral controller is given by

$$k_p\Delta + k_I \int \Delta\, dt \quad (10)$$

$$\Delta = SP - PV. \quad (11)$$

$$c = \frac{G(1+\tau s)}{\tau s} \quad (12)$$

Setting an incentive for G is frequently a tradeoff between diminishing overshoot and expanding settling time. Enduring state blunder decreased to zero by basic term which won't occurred corresponding term just in the controller The current-mode control plot is exhibited in Fig.3 An extra internal control circle bolsters back an inductor current sign, and this present sign, changed over into its voltage simple, is contrasted with the control voltage. This alteration of supplanting the sawtooth waveform of the voltage-mode control plot by a converter current sign altogether modifies the dynamic conduct of the converter, which at that point takes on certain attributes of a present source.

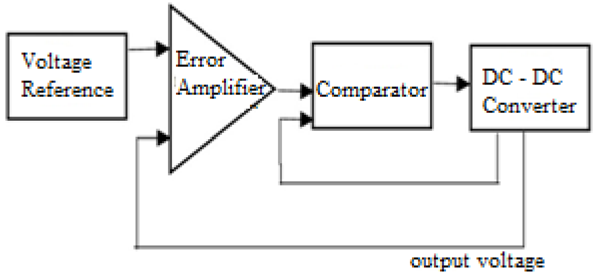

Figure. 3: Current mode control of PI control

The current-mode control relative necessary controller is appeared in Fig.3. An extra internal control circle bolsters back an inductor current sign, and this present sign, changed over into its voltage simple, is contrasted with the control voltage. This alteration of supplanting the sawtooth waveform of the voltage-mode control conspire by a converter current sign fundamentally adjusts the dynamic conduct of the converter, which at that point takes on certain attributes of a present source.

The yield current in PWM converters is either equivalent to the normal estimation of the yield inductor current or is a result of a normal inductor present and an element of the obligation proportion. In down to earth executions of the current-mode control, it is possible to detect the pinnacle inductor current rather than the normal worth. As the pinnacle inductor current is equivalent to the pinnacle switch current, the last can be utilized in the internal circle, which frequently disentangles the present sensor. Burden of this present mode control procedure is it's unpredictability in equipment. Which incorporates remunerating control voltage by incline flag to such an extent that converter shakiness can be dodged. Hysteresis current control technique is basic in equipment and can be effectively executed.

B. Adaptive Neuro Fuzzy Inference System (ANFIS) Controller

The Sugenotype Fuzzy inference engine that provides linear outputs for non-linear inputs is developed for ANFIS controller. The two inputs that are provided are the error of the currents and the change in error of the currents. Both the inputs are given with nine membership functions. All the membership functions are of triangular in nature. 81 fuzzy rules were written to realize the controller [10]. The ANFIS controller is trained with the Back Propagation Network algorithm with 10 iterations.

A current controlled strategy is developed by adopting the concept of adaptive neuro fuzzy inference system (ANFIS) to reduce the spike occurring in the primary current of a welding transformer. ANFIS is effectively control the state of the welding transformer. In the ANFIS technique, the information is gotten at the data sources and travels through the framework, layer by layer, till it arrives at the yields. The main contribution to the ANFIS is spoken to by the w (t). circle and square hubs are utilized in a versatile system to speak to versatile abilities. a square hub is named as versatile hub and the circle hubs are named as fixed hubs separately.

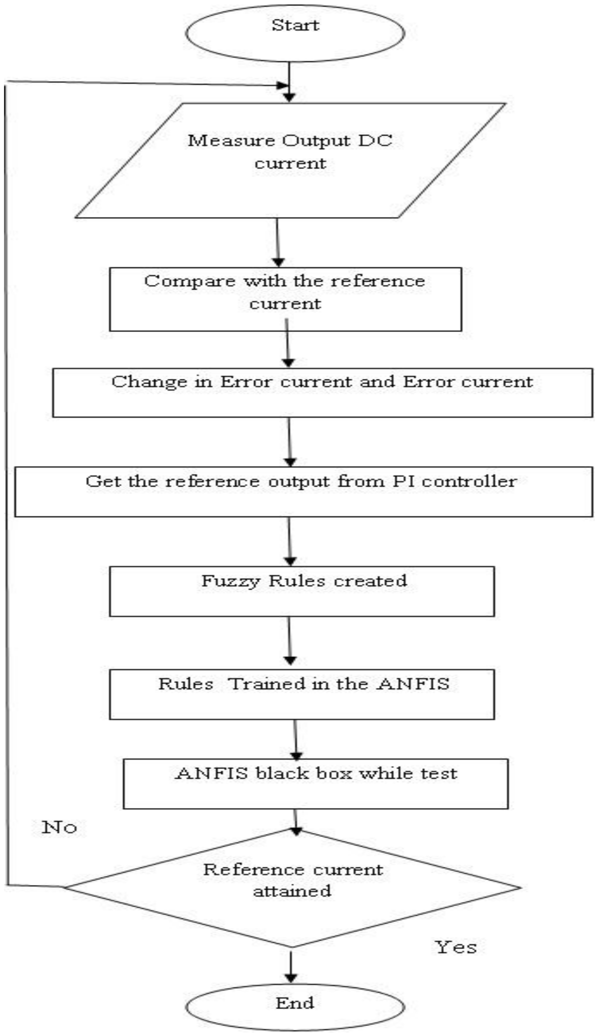

Fig. 4. ANFIS controller algorithm

The learning calculation adjusts the participation elements of a Fuzzy Inference System by methods for the preparation input-yield information. Here, the information yield information speaks to the "facilitates edges" dataset. The directions work as contribution to the ANFIS and the edges speak to the yield. The rearrangements aptitude is ventured up just if the ANFIS framework is home to a fitting number of rules. The ANFIS framework has ended up broadly utilized in order to viably deal with certain machining strategies, which are commonly utilized in the reliable control systems. With the expectation of understanding a favored information yield mapping, these imperatives are overhauled as per a predefined preparing information and an angle based learning process [9]. In the replication procedure, the ANFIS configuration is used to offer shape to a non direct capacity, and find nonlinear modules in an administration instrument. The angle strategy and the least squares assessment are coordinated to invigorate the imperatives in a versatile framework. Every single age of the cross breed learning process is home to a forward pass and a regressive pass. The forward pass is endowed with capacity of spreading the information vector through the system layer by layer.

In the retrogressive pass, the mistake is sent back through the framework in an indistinguishable technique to back proliferation. The calculation for ANFIS controller has appeared in figure 4.

IV RESULTS AND DISCUSSION

MATLAB/SIMULINK software package is used to implement the RSWS with current control technique for controlling the saturation level in the magnetic core of a weding transformer as discussed in above sections for classical (PI) and intelligence controller. The Total Harmonic Distortion (THD), variation of flux have been observed. ripple content in welding current and spike reduction percentage has been calculated. Variation of rise time and settling time also noticed.

THD in PI controller 37.32% where as in ANFIS controller 35.89%. so, reliability is more in ANFIS control than PI control.

Flux is varied within the standard limits of 0 to 1.5 wb in ANFIS controller and can be seen symmetrical behavior but in PI controller flux not varied within the standard limits and varied unsymmetrically. So magnetization level control can be done effectively in intelligence control. Behavior of flux in PI controller and Intelligence controller have shown in fig.6 and 10.

Welding current is the input for the controllers. Ripple content in the welding current is calculated as

$$Ripple = \frac{I_{hss} - I_{lss}}{I_{ave}} X100 \qquad (13)$$

where I_{hss} is peak current at high side and

I_{lss} is peak current at low side in the triangular portion of the steady state current.

I_{ave} is the average of the triangular wave. Ripple content of the controllers are also tabulated.

Spike in primary current of transformer is calculated for both controllers as

$$Spike = \frac{I_{prp} - I_{pra}}{I_{pra}} X\,100 \qquad (14)$$

Spikes reduction in percentage has also tabulated in the table. From the table shown below, in all aspects, ANFIS controller shown better results than PI controller.

Table. 1:

Method	THD (%)	Welding Current Ripple(%)	Current Spike Percentage(%)	Settling time in millisecs	Rise Time millisecs
PI	37.32	5.88	1.428	0.03	0.017
ANFIS	35.8	4.7	0.25	0.024	0.0102

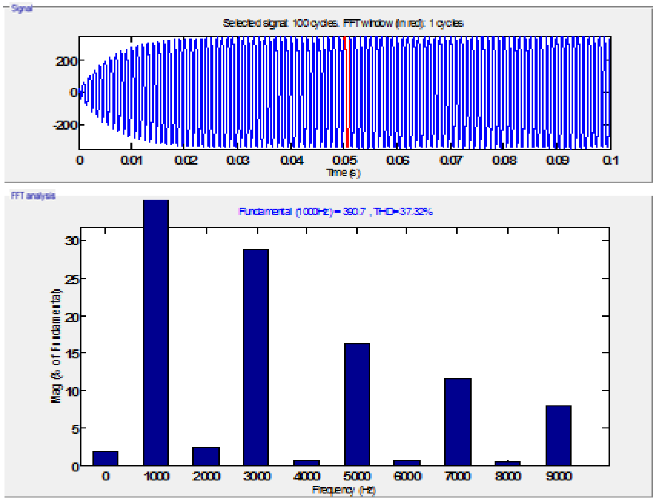

Figure. 5. Total Harmonic Distortion in PI controller

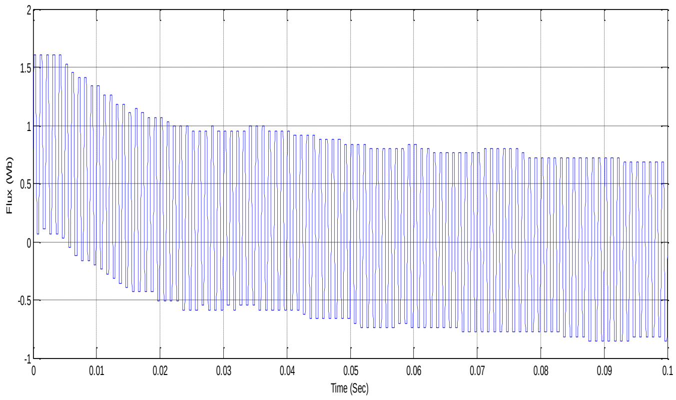

Fig. 6. Flux Response with PI controller

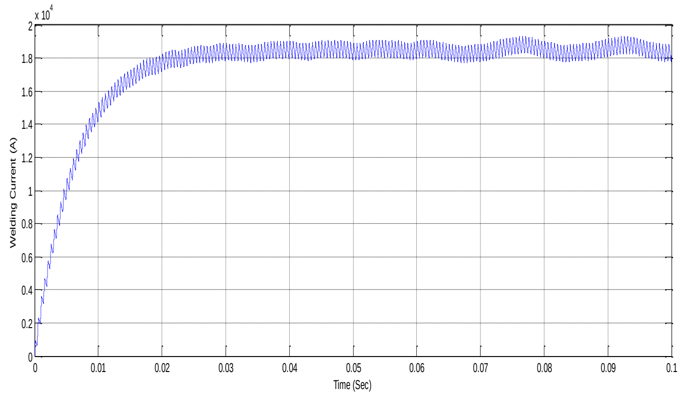

Fig. 7. Welding Current with PI Controller

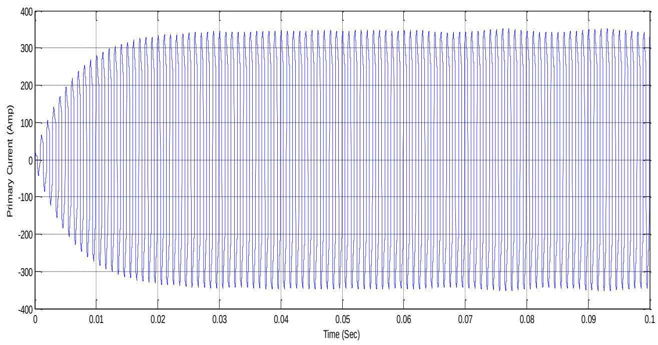

Fig. 8. Primary Current of transformer with PI controller

ANFIS Controller:

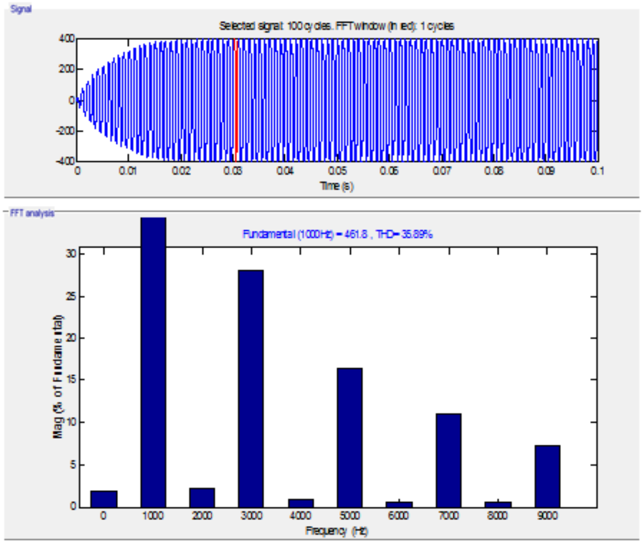

Fig. 9. Total Harmonic Distortion in ANFIS controller

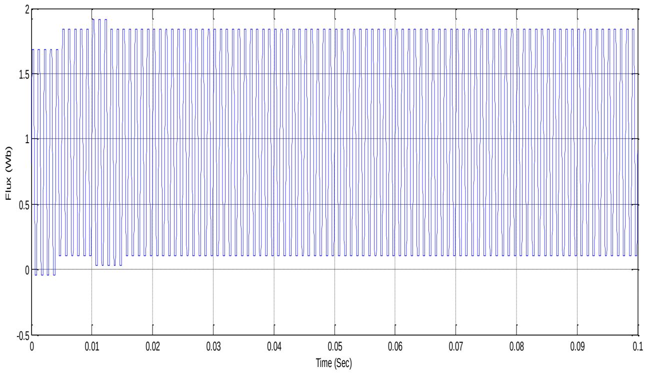

Fig. 10. Flux Response with ANFIS controller

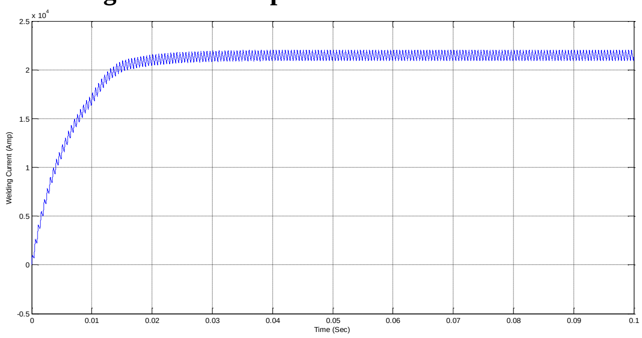

Fig. 11. Welding Current with ANFIS Controller

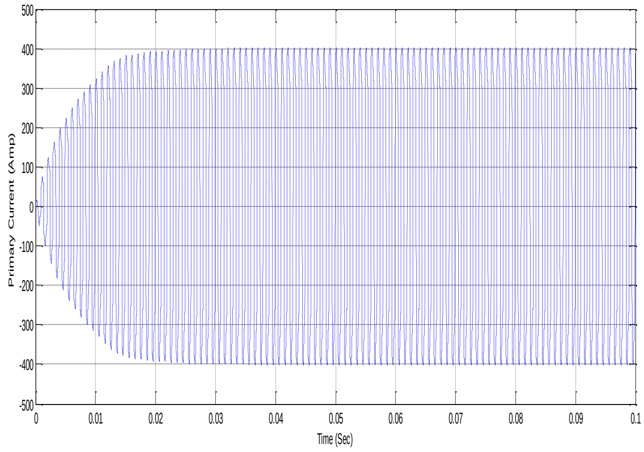

Fig.12. Primary Current of transformer with ANFIS controller

IV. CONCLUSION

Research in this paper is carried out on two controllers, i.e classical controller(PI) and intelligence controller (ANFIS). Observed performance of both controllers in terms of THD, ripple content in welding current, spike reduction percentage in primary current, rise time and settling time. As it is mentioned in the table.1, reduction in current spike in PI controller 1.428% is reduced to 0.25% with intelligence controller which is a major improvement and crucial parameter to consider for uninterrupted and reliable spot welding system. One more important parameter in this research is THD which is 37.32% in PI controller is reduced to 35.8% with ANFIS controller will results in effective performance of the controller. Rise time , settling time and ripple content in welding current are improved with intelligence controller. overall Observation through simulation of the controllers proved that the intelligence controller is superior than the classical controller in all above mentioned parameters.

REFERENCES

1. J. Cale; C. Lute; J. Simon; A. Delcore "Modeling Minimally-Processed Shielded Metal Arc Weld Transformers for Rural Minigrid Applications" Modeling Minimally-Processed Shielded Metal Arc Weld Transformers for Rural Minigrid Applications
2. Feng-Que Pei ; Yi-Fei Tong ; Dong-Bo Li "Multi-Level Welding Quality Fault Discovery of an Intelligent Production Line by Using Taguchi Quality Loss Function and Signal-Noise Ratio", IEEE Access Year: 2018 | Volume: 6 | Journal Article | Publisher: IEEE
3. LI Ru-xiong and Jiao Song-hua ," Analyzing system of electric signals in spot welding process ",International Conference on Computer Science and Information Processing (CSIP) ,IEEE,2012
4. BenoKlopˇciˇc et al, "Advanced Control of a Resistance SpotWelding System" IEEE Transactions On Power Electronics, Vol. 23, No. 1, January 2008.
5. KlemenDeželak et al," Artificial Neural Network Applied forDetecting the Saturation Level in theMagnetic Core of a Welding Transformer", Artificial Neural Networks - Industrial and Control Engineering Applications.
6. G. Shirkoohi, **et al** "Dependence of Magnetization near Saturation on Alloying Content in Ferromagnetic Steel". *IEEE Transactions on Magnetics*, Vol. 51, No. 7. 2015**.**
7. Wei-Hsiang Ko ; Jyh-Cherng Gu ; Wei-Jen Lee "Energy Efficiency Improvement of a Single-Phase AC Spot Welding Machine by Using an Advanced Thyristor Switched Detuning Capacitor Bank" IEEE Transactions on Industry Applications Year: 2018 | Volume: 54, Issue: 3 | Journal Article | Publisher: IEEE.
8. Rama Subbanna.S. **et al** "" Control of Saturation level in the magnetic core of a welding transformer by Hysteresis Controller (HC) and Proportional Integral (PI) Controller" Int. Journal of Engineering Research and Application www.ijera.com ISSN : 2248-9622, Vol. 6, Issue 12, (Part -1) December 2016, pp.78-85.
9. F. de Leon **et al** "Complete transformer model for electromagnetic transients," *IEEE Trans. Power Del.*, vol. 9, no. 1, pp. 231–239, Jan. 1994.
10. Rama Subbanna.S. ***et al*** **"**Intelligent Control System For Resistance Spot Welding System **"** i-manager's Journal on Instrumentation & Control Engineering, Vol. 6 l No. 4 l August - October 2018.

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