ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 2, April 2014

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

Fuzzy Logic based Soft Starting of Three Phase Induction Motor

Mohamed Wasim Ansari.K[1], Mohanasundaram.K[2], Mohan.C[3]

UG Student, Dept. Of EEE, R.M.K Engineering College, Tiruvallur, Tamil Nadu, India [1]

Associate Professor, Dept. Of EEE, R.M.K Engineering College, Tiruvallur, Tamil Nadu, India [2]

UG Student, Dept. Of EEE, R.M.K Engineering College, Tiruvallur, Tamil Nadu, India[3]

ABSTRACT: This paper presents the current control of three phase induction motor using Fuzzy logic. A thyristorized AC voltage Inverter is utilized as the starting equipment while the motor current regulation is carried out using an optimally tuned Proportional-Integral (PI) controller. AC voltage Inverter fed starting of induction motor is a non-linear process. The complete drive system including AC voltage inverter fed induction motor in conjunction with PI controller is optimized using Fuzzy logic. The successful implementation with a low cost microcontroller demonstrates the feasibility of the new approach. The simulation is carried out by Matlab/Simulink.

KEYWORDS: Induction Motor, Fuzzy Logic, AC voltage inverter.

I. INTRODUCTION

The various methods of starting of three-phase induction motor generally falls into four basic categories [1]: direct online starting, electromechanical reduced voltage starting, solid-state reduced voltage starting and variable-frequency-drive (VFD) starting. The cheapest way is direct online starting, but the limitation with this method is large initial current surge leading to voltage dips in the supply system. Auto-transformer starting, star/delta starting and resistor/reactor starting are a part of Electro-mechanical reduced-voltage starting. Among these, star/delta starting is more popular since it is cheap, compact and causes no power loss. However this method can be applied only for normally delta-connected stator provided with six leads. Conventional starting elements require some type of mechanical switch or contact and have several drawbacks[2,3], such as need for frequent inspection and maintenance, non-simultaneous switching of motor phases to the supply, failure in the moving parts due to large amount of switching, etc.

With the development of solid state starters, conventional starters have been replaced by starters that employ high-power devices. An earlier work in this regard is seen in [4,5]. The solid state starter consisted of a pair of back-to-back connected SCRs and the firing angle of SCRs was varied to control the rate of change of KVA with respect to time. A solid state voltage contactor employing anti-parallel SCRs is given in [7]. The concept of use of SCR voltage inverter with firing angle control for smooth induction motor starting is labelled as “soft starter”. A closed loop optimal soft starting ac voltage controller fed induction motor drive based on voltage across the thyristor is seen in [9]. While earlier works were confined to current limit starting, performance enhancement of starting torque was later addressed [10,11]. Numerical solution method is attempted in [10] for improved starting current and torque profile whereas the method suggested in [11] consists of two parts: a linear initial firing angle scheme which eliminates starting torque ripples and a current control strategy which consists of successive sinusoidal and constant function segments of triggering angle of SCRs. A soft starter with voltage and power factor angle as feedback signals is given in [12], whereas starting torque optimization is carried out in [13]. The work in [14] explains the use of Artificial Neural Network (ANN) for the generation of SCR firing angles for soft starting. Soft starters are employed for energy saving too[15,16]. While the schemes in [4–7] are of open loop type, the soft starters in [8–14] work in closed loop mode. The closed loop control strategies are obtained by repeatedly simulating the motor model several times and employing trial and error based approach. Soft-starter has been increasingly employed in the industries now-a-days, yet the design procedure of feedback controller for rated current starting is not available in literature. This is important in particular because, AC

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 2, April 2014

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

voltage controller fed induction motor drive system is described by a highly non-linear fifth order differential equation. This demands a detailed design and implementation of a feedback controller for soft-starter fed induction motor drive. In this paper, the feedback controller design is formulated as an optimization problem and the solution is achieved to obtain good dynamic response. A close examination of the available research work indicates that systematic design and implementation of a soft-starter with PI controller is not available in the literature. This paper proposes an optimization model for PI controller based motor current regulation during motor starting. The optimization model makes use of d–q axis model for evaluating objective function and is simulated through Fuzzy logic.

II. FUZZY LOGIC BASED PI CONTROLLER DESIGN

The schematic of three-phase AC voltage inverter fed induction motor starting using closed loop current controller is shown in Fig. 1. Here, the power converter employed is a three-phase AC voltage inverter employing SCRs. The SCR firing angle is varied to adjust the stator voltage applied to the motor. The AC voltage controller consists of six SCRs labelled as T1, T′1, T2, T′2, T3 and T′3.The SCRs T1 and T′1 are triggered at a delay of α and π+α respectively with reference to the zero crossing of R-phase voltage V_{RN}. The SCRsT2 and T′2 are triggered at a delay of (2π/3)+α and (2π/3)+(π+α) respectively. In a similar manner, the SCRs T3 and T′3 are triggered at a delay of (4π/3) + α and (4π/3) + (π+α) respectively. The heart of the closed loop system is PIC16F87XA micro controller which works as digital PI controller as well as firing pulse generator. The R-phase voltage, V_{RN} is stepped down and converted into a digital pulse using Zero Crossing Detection (ZCD) circuit and this pulse is fed to the pin RC_0 of the microcontroller. The micro-controller senses the status of this pin each time and once zero crossing signal has come, it starts producing six firing pulses through RB_0 to RB_5 with a delay angle α computed by the PI controller realized in the microcontroller.

The schematic of three-phase AC voltage inverter fed induction motor starting with closed loop current controller is shown in Fig. 1.

The stator voltages V_{ds} and V_{qs} are given by,

$$\begin{bmatrix} Vds \\ Vqs \end{bmatrix} = \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Vrs \\ Vys \\ Vbs \end{bmatrix} \quad (1)$$

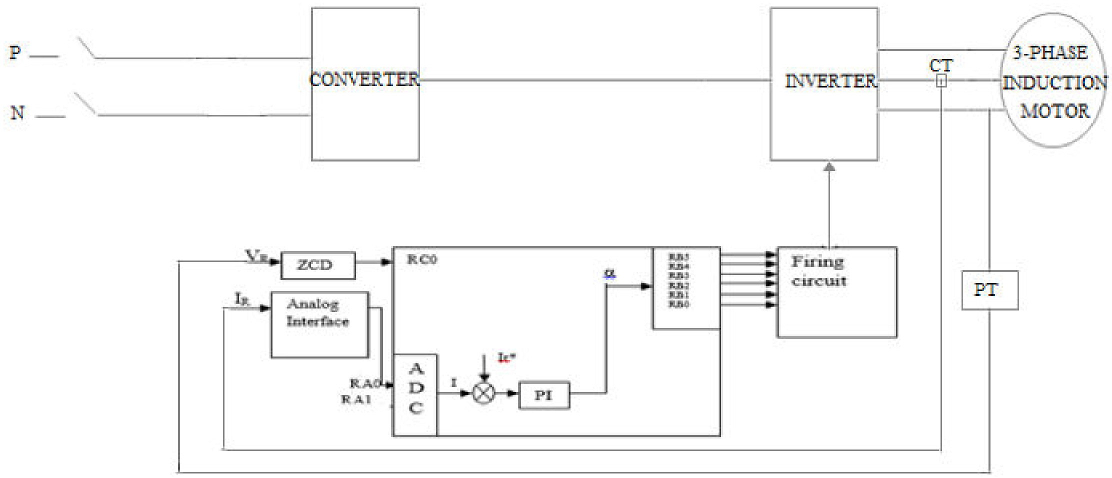

Fig.1 Block diagram of Induction motor soft-starting with feedback controller.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 2, April 2014*

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

The inputs to this model are SCR firing angle α and load torque TL. Since motor starting is carried out on no-load, T_L is made zero throughout starting and firing angle α is updated through the PI controller. The motor current evaluated through the model is then compared with rated motor current Ir*and the error is given to the PI controller which calculates the change in firing angle Δα. The value of α_0 indicates initial SCR firing angle and is suitably selected.

Here, the task is to keep the motor current constant throughout starting. Thus if Ir * is rated current of motor and Iris the instantaneous current during starting, then soft starting can be performed if Iris maintained at Ir*.

Fuzzy logic provides a strong framework for achieving robust and simple solutions among different approaches of Intelligent computation. Fuzzy model is a collection of IF - THEN rules with vague predicates that use a fuzzy reasoning such as Sugeno and Mamdani models. Sugeno type systems can be used to model any inference system in which the output membership functions are either linear or constant whereas Mamdani type produces either linear or nonlinear output. The fuzzy logic controller consists of four stages: fuzzification of inputs, derivation of rules, inference mechanism and de-fuzzification. Fuzzy logic systems are universal function approximators. In general, the goal of fuzzy logic system is to yield a set of outputs for given inputs in a non-linear system, without using any mathematical model but by using linguistic rules. A general block diagram of Fuzzy logic is given in Fig.2.

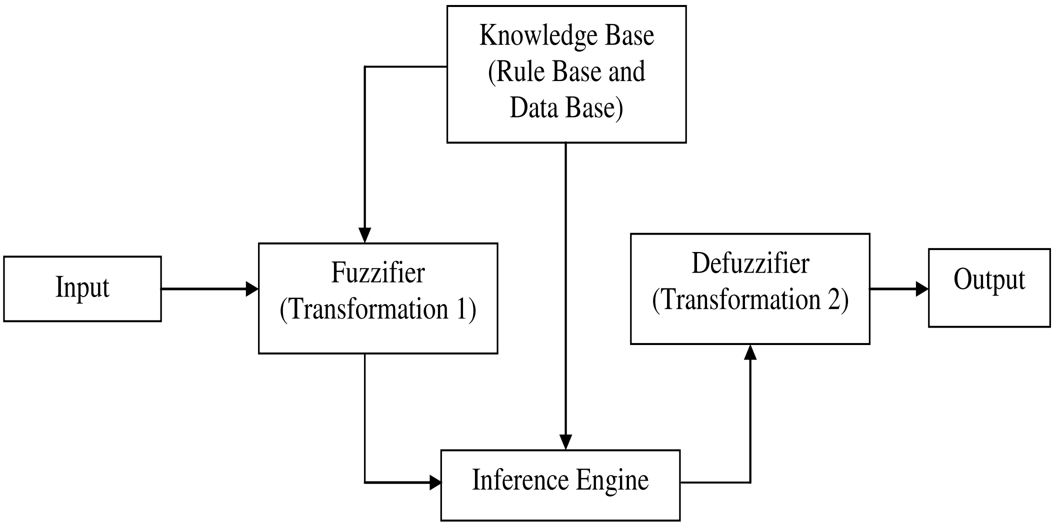

Fig 2. Block Diagram of Fuzzy Logic

IJIRSET

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 2, April 2014*

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

III. RESULTS

A dedicated Fuzzy based model is developed in MATLAB for the feedback controller design.
The results obtained through simulation are given in Fig.3. These results depict the early settling time of the starting current which is close to 0.3 seconds.

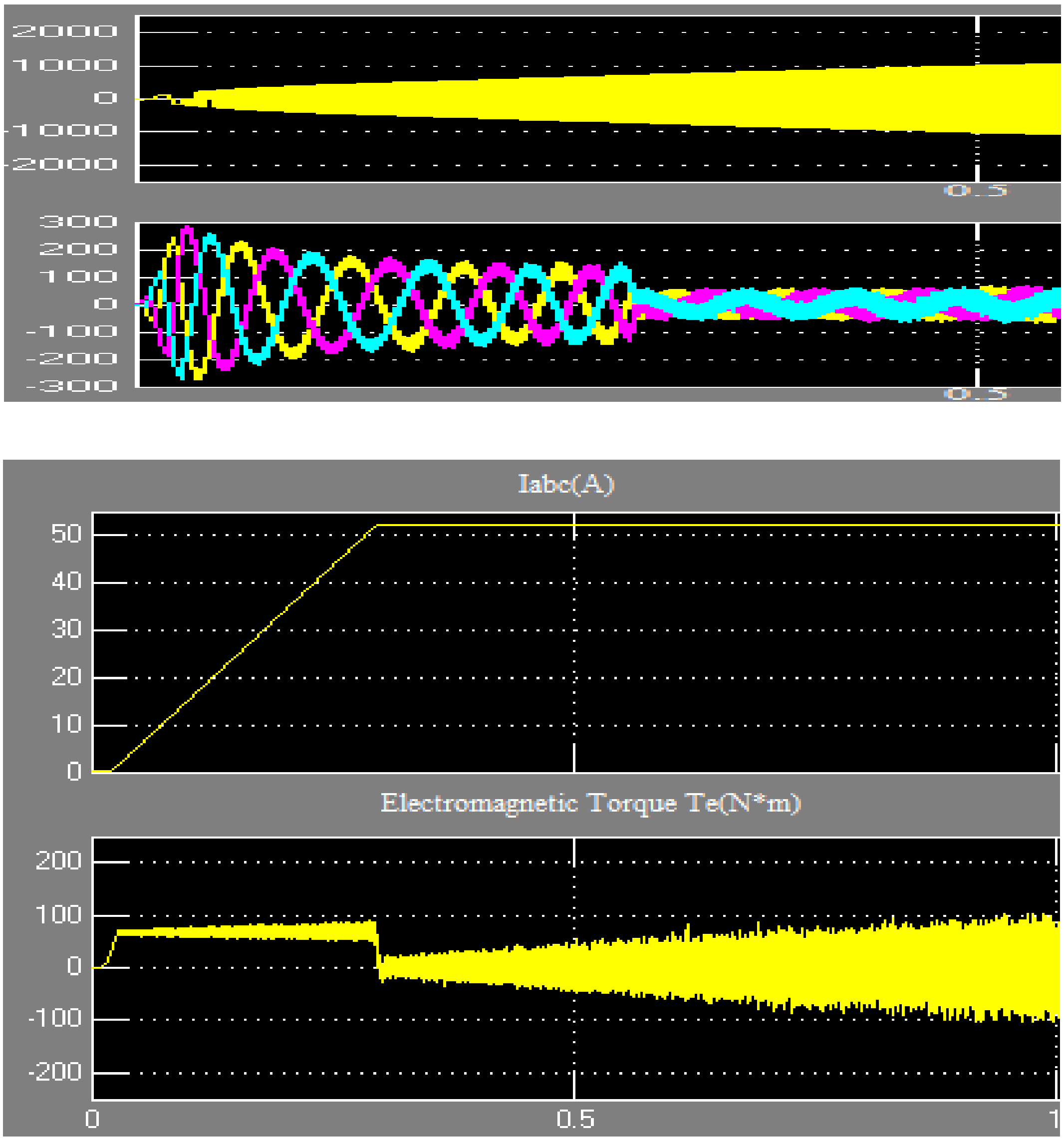

Fig. 3.MATLAB Simulation output (a) Voltage (b) Current(3 phase notation) (c) Current(graphical notation) and (d)Torque

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization   Volume 3, Special Issue 2, April 2014

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

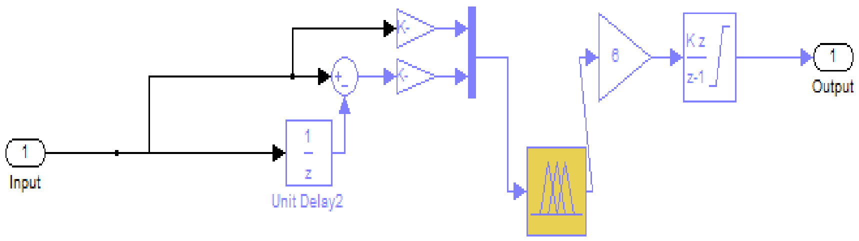

Fig. 4 Fuzzy Controller model

IV. CONCLUSION

This work has focused on the design and implementation of a closed loop scheme for soft-starter fed induction motor drive with PI controller. The objective of the closed loop operation was to start the motor at rated current. Towards this goal, soft-starter fed induction motor drive with closed loop operation is first modelled in MATLAB. The complete drive system is simulated using Fuzzy Logic in MATLAB. PIC16F87XA microcontroller is used as the feedback controller and firing pulse generator for AC voltage inverter. The computed results validate the proposed method.

Table 1.
Parameters of Induction motor

Parameters	Value
Stator resistance Rs	0.0823
Rotor resistance Rr	0.0503
Stator inductance Ls	0.724e-3H
Rotor inductance Lr	0.724e-3H
Voltage rating	415 V
Speed	1430 RPM
Current	3 A
Rating	5.4 KW
Frequency	50 Hz

REFERENCES

[1] R.F. Mc Elveen, M.K. Toney, Starting high inertia loads, IEEE Trans. Ind. Appl. 37(January–February (1)) (2001) 137–144.
[2] E.P. Dick, B.K. Gupta, P. Pillai, A. Narang, T.S. Lauber, D.K. Sharma, Pre striking voltages associated with motor breaker closing, IEEE Trans. Energy Convers.3(December (4)) (1988) 855–863.
[3] H.G. Tempelaar, Determination of transient voltages caused by switching of high voltage motors, IEEE Trans. Energy Convers.3 (4) (1988) 806–814.
[4] J.P. Colleran, W.E. Rogers, Controlled starting of AC induction motors, IEEE Trans. Ind. Appl., IA-22 vol. IA-19 (1983) 1014–1018.
[5] F.M. Bruce, R.J. Graefe, A. Lutz, M.D. Panlener, Reduced-voltage starting of Squirrel-cage induction motors, IEEE Trans. Ind. Appl. vol. IA-20 (1984) 46–55 Jan/Feb.
[6] J. Bowerfind, S.J. Campbell, Application of solid-state AC motor starters in then pulp and paper industry, IEEE Trans. Ind. Appl., IA-22 (January/February) (1986)109–114.
[7] D. Gufflet, P. Malkin, Solid state medium voltage contactor, IEE Proc. B, Electr. Power Appl. 140 (March (2)) (1993) 147–151.
[8] V.V. Sastry, M.R. Prasad, T.V. Sivakumar, Optimal soft starting of voltage controller-fed IM drive based on voltage across thyristor, IEEE Trans. Power Electron. 12 (November (6)) (1997) 1041–1051.
[9] W. Shepherd, On the analysis of three phase induction motor with voltage control by thyristor switching, IEEE Trans. Ind. Gen. Appl. 4 (May/June) (1968)304–311.
[10] T.A. Lipo, The analysis of induction motors with symmetrically triggered thyristors, IEEE Trans. Power App. Syst., PAS-90 (March/April) (1971)515–525.

[11] G. Nath, G.J. Berg, Transient analysis of three-phase SCR controlled induction motors, IEEE Trans. Ind. Appl. 17 (March/April) (1981) 133–142.

[12] S.S. Murthy, G.J. Berg, A new approach to dynamic modelling and transient analysis of SCR controlled induction motors, IEEE Trans. Power App. Syst., PAS-1019 (September) (1982) 219–229.

[13] L.X. Le, G.J. Berg, Steady-state performance analysis of SCR controlled induction motors: a closed form solution, IEEE Trans. Power App. Syst. 103 (March) (1984)601–611.

[14] F.M.H. Khater, D.W. Novotny, An equivalent circuit model for phase back voltage control of AC machines, IEEE Trans. Ind. Appl. 22 (September/October)(1986) 835–841.

[15] (a) S.A. Hameed, B.J. Chalmers, Analysis of variable-voltage thyristor controlled induction motors, IEE Proc. B, Electr. Power Appl. 137 (May (3)) (1990)184–193.

(b) I. Cadrici, M. Ermis, E. Nalcaci, B. Ertan, M. Rahman, A solid state direct on line starter for medium voltage induction motors with minimized current and torque pulsations, IEEE Trans. Energy Convers. 14 (September (3)) (1999)402–412.

[16] K. Sundareswaran, B.M. Jos, Development and analysis of novel soft starter/energy-saver topology for delta-connected induction motors, IEE Proc.:Electr. Power Appl. 152 (July (4)) (2005).

[17] M. Dorigo, V. Maniezza, A. Colorni, Ant system: optimization by a colony of co-operation agents, IEEE Trans. Syst. Man Cybern., Part B: Cybern. 26 (February(1)) (1996) 29–41.

[18] M. Dorigo, C. Blum, Ant colony optimization theory: a survey, Theor. Comput.Sci. 344 (November (2–3)) (2005) 243–278.

[19] Z. Jun, H.S.H. Chung, A.W. Lo, H. Tao, Extended ant colony optimisation algorithm for power electronic circuit design, IEEE Trans. Power Electron. 24(January (24)) (2009) 147–162.

[20] C.M. Colman, J.E. Rothwell, J.E. Ross, Investigations of simulated ant colony optimizations and genetic algorithms for self-structuring antennas, IEEE Trans. Antennas Propag. 52 (April (4)) (2004) 1007–1014.

[21] Chia-Feng Juang, Chun-Ming Lu, Chiang Lo, Chi-Yen Wang, Ant colony optimization algorithm for fuzzy controller design and its FPGA implementation,IEEE Trans. Ind. Electron. 55 (March (3)) (2008) 1453-1462.

[22] P. Puranik, P. Bajaj, A. Abraham, P. Palsodkar, A. Deshmukh, Human Perception based Color Image Segmentation Using Comprehensive Learning ParticleSwarm 20 Optimization, Journal of Information and Multimedia Signal Processing2 (3 Jul.) (2011) 227–235.

[23] F.C. Chang, H.C. Huang, A refractoring method for cache-efficient swarm intelligence algorithms, Inf. Sci., doi:10.1016/j.ins.2010.02.025.

[24] C.H. Hsu, W.J. Shyr, K.H. Kuo, Optimizing multiple interference cancellations oflinear phase array based on particle swarm optimization, J. Inf. Hiding Multimedia Signal Process. 1 (4 October) (2010) 292–300.

[25] H.C. Huang, C.M.Chu, J.S. Pan, The optimized copyright protection system with genetic watermarking, Soft Comput.13 (February (4)) (2009)333–343.

[26] P.C. Krause, Analysis of Electric Machinery, McGraw-Hill, New York,1986.

[27] M.G. Say,Alternating Current Machines, 5th ed., ELBS, London, 1992.

[28]. Mr.Hemant Amhia, Sharda Patwa, Analysis and Control of Starting Current of Three Phase Induction Motor by Fuzzy Logic Controller, IOSR Journal of Engineering (IOSRJEN)November2012.

[29]. S.senthilkumar, S.Vijayan, Fuzzy based Speed Control of Three phase Induction Motor, International Journal of Engineering Science and Innovative Technology (IJESIT), November 2013.