International Research Journal of Engineering and Management Studies (IRJEMS)
Volume: 03 Issue: 05 | May -2019 ISSN: 2395-0126

Fuzzy Logic and Artificial Neutral Network Control of SRM fed through an Asymmetric Converter

G M KHAN[1], I VAMSI RAM[2]
Faculty of Electrical Engineering (BVCITS), AMALAPURAM,
. E-mail: mohiddinkhan.15@gmail.com,vamsiram.illa@gmail.com,gmganesh214@gmail.com

***Abstract*— Switched reluctance motor is an electric motor which possesses advantageous features that qualifies it to be used in electric vehicle and aerospace application. There are various drivers have been previously and actively being used to drive the switched reluctance motor. In this paper, the switched reluctance motor is controlled utilizing vector control using fuzzy logic controller and ANN controller in order to minimize the torque ripple by regulating torque within specified hysteresis band. Both fuzzy logic and ANN Control of Switched Reluctance Motor fed through an asymmetrical converter. Both of controllers are simulated in MATLAB/ SIMULINK for fixed SRM parameters. According to the obtained results the switched reluctance motor is performing very well when driven by fuzzy logic controller in comparison to the ANN controller.**

Keywords—SRM; ANN; fuzzy logic; MATLAB/ SIMULINK

I. INTRODUCTION

The working of Switched Reluctance Motor is previously known for more than 150 years, however just some large development of the power electronics drive technologies have made a great advancement of adjusted speed drives with Switched Reluctance Motor. Due to large requirement for variable speed drives and evolvement of power semiconductors the conventional reluctance machine has been come into picture and is known as Switched Reluctance Machine. The name "Switched Reluctance", first used by one of the authors of [1], describes the two features of the machine configuration (a) switched, (b) reluctance.

A SRM has salient poles on both stator and rotor. Each stator pole has a simple concentrated winding, where the rotor does not contain any kind of winding or permanent magnet [2]-[4]. It is made up of soft magnetic material that is laminated steel. Two diametrically opposite windings are connected together in order to form the motor phases. During the rotor rotation a circuit with a single controlled switch is sufficient to supply an unidirectional current for each phase. For forward motoring operation the stator phase winding must be excited when the rate of change of phase inductance is positive. Otherwise the machine will develop breaking torque or no torque at all. As SRM has simple, rugged construction, low manufacturing cost, fault tolerance capability and high efficiency the SRM drive is getting more and more recognition among the electric drives. It also have some disadvantages that it requires an electronic control and shaft position sensor and double salient structure causes noise and torque ripple. SRMs are typically designed in order to achieve a good utilization in terms of converter rating.

The machine operation and salient feature can be deduced from the torque expression. The torque expression is nothing but the relationship between machine flux linkages or inductance and rotor position. The torque v/s speed characteristics of the machine operation in all of its four quadrants can be derived from the inductance v/s rotor position characteristics of the machine. Switched Reluctance Machine can be designed of any phases. For single phase machine it have low performance but high volume application Switched Reluctance Motor can be made up of laminated stator and rotor cores with Ns =2mq poles on the stator and Nr poles on rotor. Where m is number of phases and each phase made up of concentrated windings placed on 2q stator poles. Switched reluctance motor is having salient pole stator with concentrated winding and salient pole rotor with no winding or permanent magnet. As both stator and rotor have salient pole structure, hence we can say that switched reluctance motor is having doubly salient structure which is single excited with different number of stator and rotor poles. It is constructed in such a manner that in no way the rotor poles in a position where the torque due to current in any phase is zero. The common stator/rotor pole configuration are 6/4,8/6,10/8. In stator the coils on two diametrically opposite poles are connected in series in order to form single phase. So, 6/4 stator/rotor pole configuration means that represent the 3-phase configuration of switched reluctance motor drive. Similarly 8/6 and 10/8 stator/rotor pole configuration represents the 4 and 5 phase configuration of switched reluctance motor drive[5].

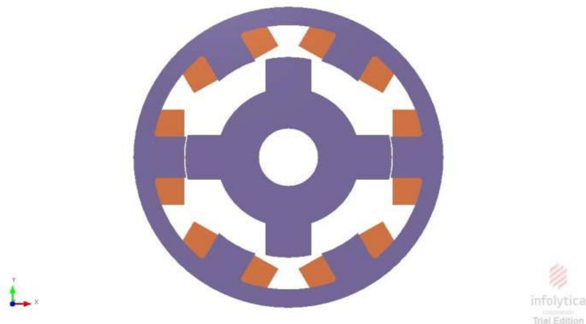


Figure 1 6/4 switched reluctance motor configuration

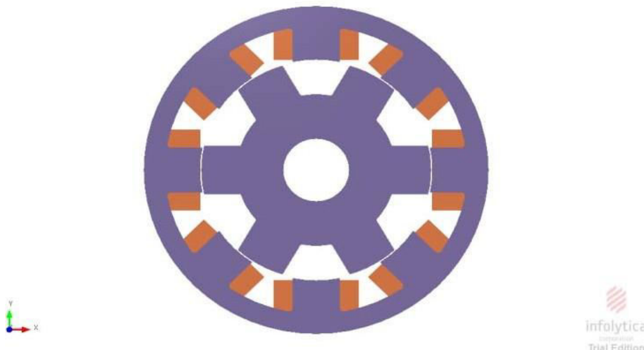


Figure 2 8/6 switched reluctance motor configuration

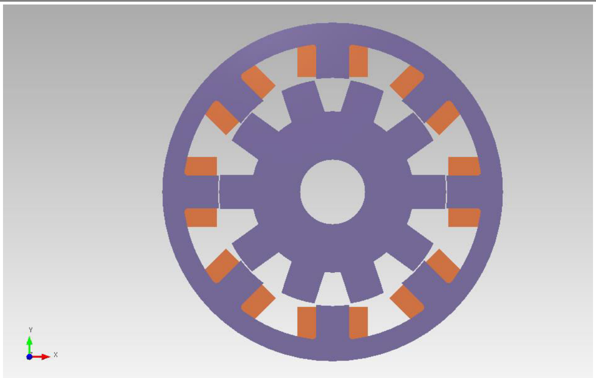


Figure 3 10/6 switched reluctance motor configuration

II. Fuzzy Logic Controler

Fuzzy logic system can be defined as a fuzzy system which utilizes a mathematical system to analyze analog input in terms of logical variables which use continuous values between 0 and 1 unlike the classic or digitalized logical which utilize digital values high(1) or low (0)[6].

Fuzzy control systems have been successfully applied to a wide variety of practical problems [7][8][9]. It has been shown that these controllers may perform better than conventional model-based controllers, especially when applied to processes difficult to model, with nonlinearities, and with uncertainties.

The fuzzy control is basically nonlinear and adaptive in nature, giving robust performance under parameter variation and load disturbance effect.

A typical fuzzy control describes the relationship between the change of the control Du(k)= u(k)-u(k-1) on one hand , and the error e(k) and its change De(k)= e(k)-e(k-1) on the other hand. Such a control law can be formalized as:

$$Du(k)=F(e(k),De(k))$$

The actual output of the controller u(k) is obtained from the previous values of control u(k-1) that is updated by Du(k) :

$$u(k) = u(k-1) + Du(k)$$

This type of fuzzy controller is known as fuzzy PI according to the relation between variables e(k) and De(k) on one hand and Du(k) on the other hand. The difference is in the type of relationship. In the case of the PI controller this relationship is linear, while in fuzzy PI it is nonlinear in general [7]. The PI controller (also fuzzy PI) is, however, known to give poor performance in transient response due to the internal integrating operation [10].

In servo motor applications the fast response of the drive is desired [11][12]. That's why the performance of fuzzy PI should be improved to give satisfactory rise time and minimum overshoot in step response. Here, the fuzzy controller system used is similar to that described by Lee [10], and it is a modified type of fuzzy P1 controller. It evaluates incremental control input (Du) and, in addition to conventional fuzzy PI, it also evaluates resetting rate (r) of control input applied to the system by error and rate of error change.

The control input is calculated by the following equation: u (k +1)=(1- sqrt(r(k))* u (k) + Du (k)

The fuzzy rules for resetting rate are constructed to damp overshoot in response by resetting accumulated control input and to make response faster under large incremental control input. Rules for calculating incremental control input (du) and resetting rate (r) are shown in Table 1. and in Table 2. Respectively. Besides, the membership functions for error (e), rate of error change (de), and incremental control input (Du) and resetting rate (r) are shown in Fig. 4 (a) - (b).

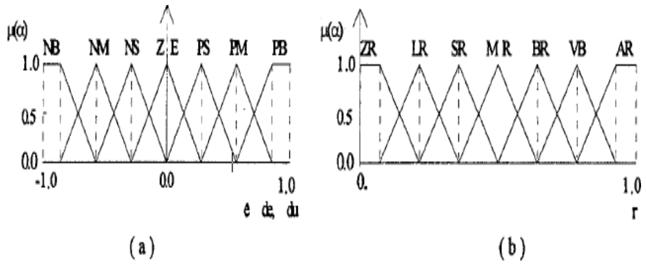


Figure 4 Membership functions for (a) error e, error rate de, incremental control input du, (b) resetting rate r .

Table 1 fuzzy control rules for calculating Du

	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	ZE	ZE	ZE
NM	NB	NB	NM	NM	NS	ZE	ZE
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NB	NS	ZE	PS	PS	PM	PB
PM	ZE	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PB	PB	PB	PB

Table 2 rules for determining resetting rate

	NB	NM	NS	ZE	PS	PM	PB
NB	ZR	SR	BR	AR	BR	SR	ZR
NM	ZR	ZR	MR	VB	MR	ZR	ZR
NS	ZR	ZR	LR	BR	LR	ZR	ZR
ZE	ZR	ZR	ZR	ZR	ZR	ZR	ZR
PS	ZR	ZR	LR	BR	LR	ZR	ZR
PM	ZR	ZR	MR	VB	MR	ZR	ZR
PB	ZR	SR	BR	AR	BR	SR	ZR

III. Artificial Neutral Network

Classical control theory suffers from some limitations due to the assumptions made for the control systems such as linearity, and time-invariance. These problems can be overcome by using artificial intelligence based control techniques. The main advantages of the artificial neural networks (ANNs) controllers are as follow [13]:

- A neural network can perform tasks that a linear program cannot.
- When an element of the neural network fails, it can continue without any problem by their parallel nature.
- A neural network learns and does not need to be reprogrammed.
- It can be implemented in any application and without any problems.
- They may require less tuning effort than conventional controller.

A three layer (2*5*1) feed forward structure with two nodes in the input layer is used. The output layer of the ANN consists of only one neuron, while the number of neurons in the hidden layer is five. The input vector consists of the motor speed error, and the previous output of the ANN. The previous output of the ANN is added to the input vector as a stabilizing signal. The activation function used is the sigmoid function in both hidden and output layer. Increasing the number of neurons in the hidden layer has the advantages of reducing the rising time (Tr) and the maximum overshoot (M.O.S) during load variation[14][15]. The output of a single neuron can be represented by the following equation:

$$a_i = f_i\left(\sum_{j=1}^{n} w_{ij} x_j(t) + b_i\right)$$

Where i f is the activation function, ij w is the weighting factor, j x is the input signal, and i b is the bias. The most commonly used activation functions are nonlinear, continuously varying types between two asymptotic values -1 and +1. They are called tansigmoid function.

IV. CONTROLLERS DESIGIN

The MATLAB SIMULINK is utilized to construct the circuit of the switched reluctance motor using Fuzzy logic controller and Artificial Neutral Network ANN. Figure 5 and 6 shows the circuit of fuzzy logic and ANN control of 8/6 switched Reluctance motor.

Figure 5 8/6 switched reluctance motor with fuzzy logic controller

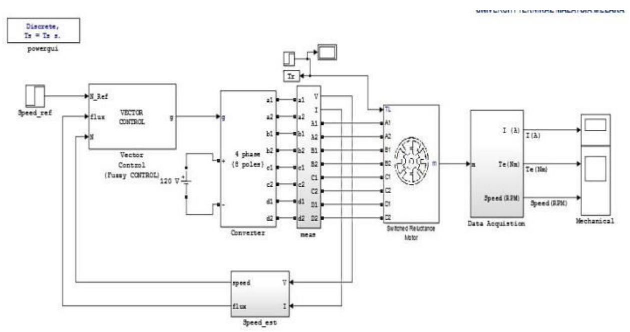
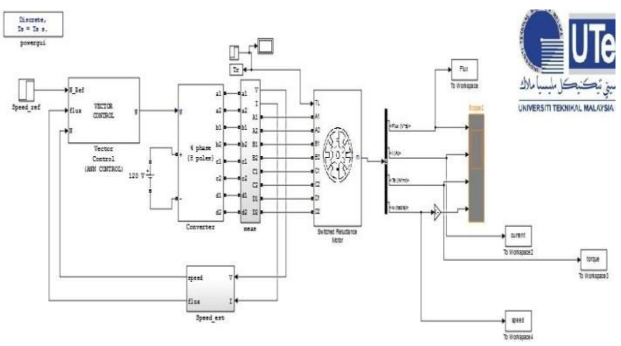


Figure 5 8/6 switched reluctance motor with fuzzy logic controller



V. SIMULATION RESULTS

The simulation results of both controller has been produced utilizing fixed parameters as in table 3

Table SRM parameters

Stator resistance (ohm)	0.01
Inertia (kg.m.m)	0.0082
Frication (N.m.s)	0.01
Initial speed and position	[0 0]
Unaligned inductance(H)	0.67e-3
Aligned inductance (H)	23.6e-3
Saturated aligned inductance(H)	0.15e-3
Maximum current (A)	450
Maximum flux linkage (V.s)	0.486

The flux of four phases switched reluctance motor utilizing fuzzy logic controller is shown in figure 7.

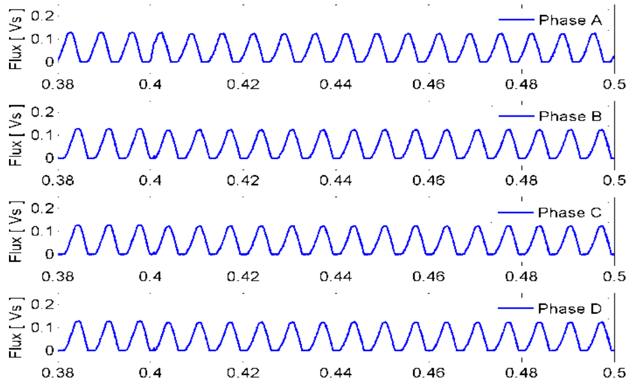
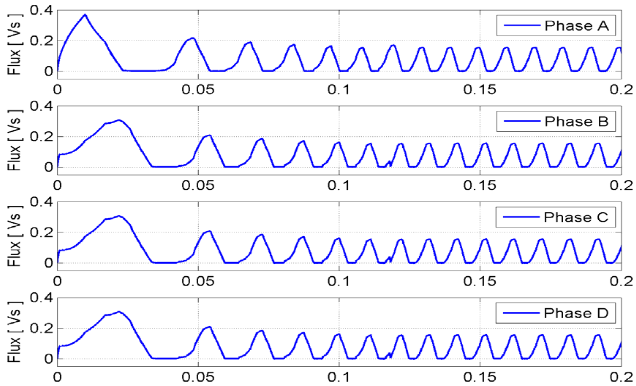


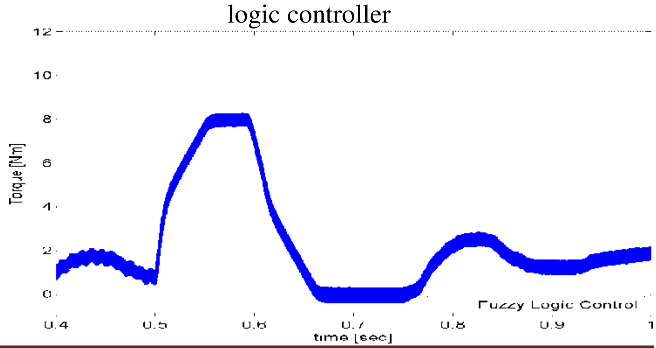
Figure 7 flux of 8/6 SRM using fuzzy logic controller

In addition the flux of the 8/6 switched reluctance motor using artificial neutral network (ANN) is shown in figure 8.



The output torque of 8/6 switched reluctance motor utilizing fuzzy logic controller is presented in figure 9.

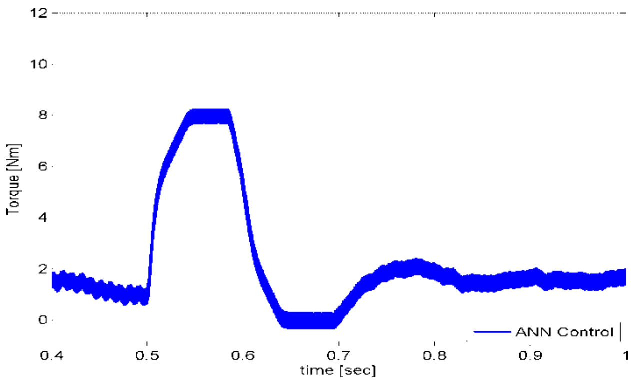
Figure 9 output torque of 8/6 SRM using fuzzy logic controller



International Research Journal of Engineering and Management Studies (IRJEMS)
Volume: 03 Issue: 05 | May -2019 ISSN: 2395-0126

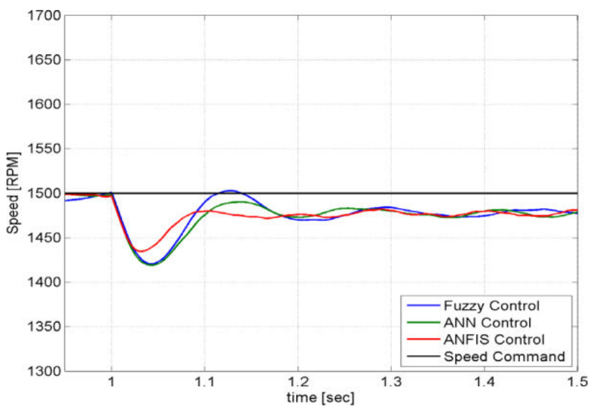
In addition, the output torque of 8/6 SRM is shown on Figure 10.

Figure 10 output torque of 8/6 SRM using ANN controller



The speed of the 8/6 switched reluctance motor utilizing fuzzy logic and ANN controller as well as ANFIS controller is presented in figure 11.

Figure 11 8/6 switched reluctance motor



Apart from that, the armature current of 4-phase switched reluctance motor using fuzzy logic controller is presented in figure 12.

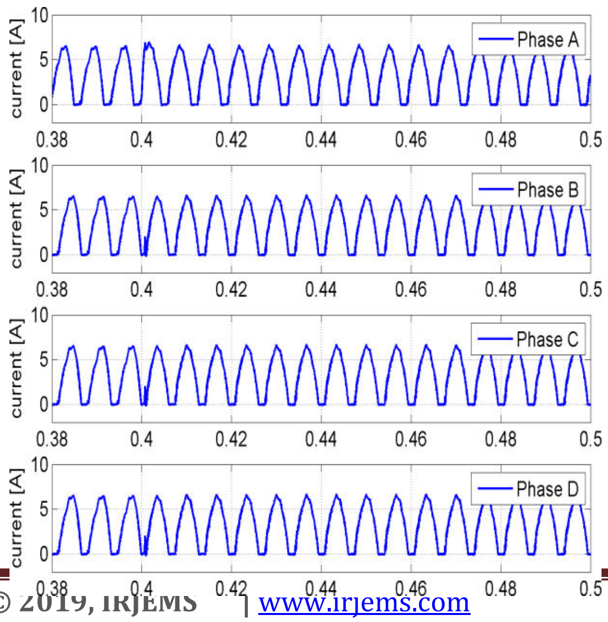


Figure 12 armature current of 8/6 SRM using fuzzy logic controller

In addition, the armature current of 8/6 SRM using ANN controller is shown in figure 13.

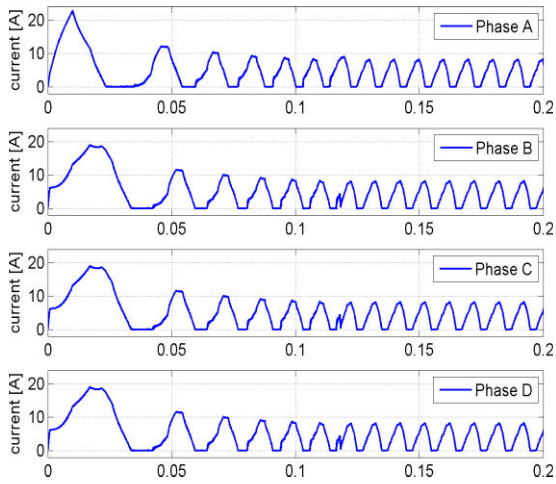


Figure 13 armature current of 8/6 SRM using ANN controller

By referring to the result 8/6 four phases switched reluctance with both fuzzy logic and ANN controller .It is clearly shown that , the fuzzy logic controller make the switched reluctance motor to perform better with less torque ripple and smooth fluxes and armature currents in comparison to ANN controller which produce more ripple and non-smooth flux and armature current .

I. Conclusion

This paper aims to study the four-phase 8/6 switched reluctance motor subjected to different controller drivers and with respect to fixed parameters .The first controller is the fuzzy logic controller and the second one is the artificial neutral network controller which both utilize bridge converter fed to the 8/6 switched reluctance motor. The simulation results obtained from MATLAB/SIMULINK has showed that the fuzzy logic controller driver produce better results in terms of less ripple torque and smooth flux and current waveform in comparison to the results obtained by ANN controller driver.

REFERENCES

[1] R. Krishnan: “Switched Reluctance Motor Drives Modeling, Simulation, Analysis, Design and Applications,” London, CRC press, 2001.

[2] T. J. E. Miller, “Converter Volt-Ampere Requirements of The Switched Reluctance Motor Drives,” in conf. Record IEEE-IAS Ann.Meeting, oct.1984, pp.813-819.

[3] R. Arumugam , D. A. Lowther, R. Krishnan and J. F. Lindsay, "Magnetic Field Analysis of A Switched Reluctance Motor Using a Two Dimensional Finite Element Model," IEEE Trans.Magnet., pp.1883-1885, sept.1985.

[4] J. Corda and J. M. Stephenson, "Analytical Estimation of The Minimum and Maximum Inductances of A Double-Salient Motor," in proc. International. conf. on stepping motors and systems, Leeds, England. 1979, pp. 50-59.

[5] Kannan, S., "Novel rotor and stator swapped switched reluctance motor," in Power Electronics, Drives and Energy Systems (PEDES), 2012 IEEE

[6] SangChul Ahn; Yong Ho Kim; Wook Hyun Kwon, "Design of a fuzzy logic controller module for a loop controller," in *Industrial Technology, 1996. (ICIT '96), Proceedings of The IEEE International Conference on* , vol., no., pp.598-602, 2-6 Dec 1996

[7] KANDEL, A., LANGHOLZ, G., Fuzzy Control System, CRC Press Inc. 1994.

[8] KUNG Y.S. , LIAW, C.M. "A Fuzzy Controller Improving a Linear Model Following Controller for Motor Drives" IEEE Trans. on Fuzzy Systems, Vol.2, No.3, Aug. 1994.

[9] SOUSA G.C.D. , BOSE, B.K. " A Fuzzy Set Theory Based Control of Phase-Controlled Converter DC Machine Drive " , IEEE Trans. on Industry App. Vol. 30, No.1, January/ February 1994.

[10] Lee, J., "On Methods for Improving Performance of P1-Type Fuzzy Logic Controllers.", IEEE Trans. On Fuzzy Sys. vol. 1, No.4, Nov. 1993

[11] TSENG.H.C. , HWANG V.H. " Servocontroller Tuning with Fuzzy Logic " IEEE Transactions on Control Systems Tecth. Vol.1. No.4, December 1993.

[12] LI, Y.F., LAU, C.C., " Development of Fuzzy Algorithms for Servo Systems ", IEEE Control System Magazine , pp.66 ,April 1989.

[13] Li, Bohu, et al. "Communications in Computer and Information Science."*Communications in Computer and Information Science* 97.PART 1 (2010).

[14] Li, B., Xu, S., Zhang, J.: Enhancing clustering blog documents by utilizing author/reader comments. In: ACM-SE 45: Proceedings of the 45th Annual Southeast Regional Conference, pp. 94--99. ACM, New York (2007)

[15] Agarwal, N., Galan, M., Liu, H., Subramanya, S.: Clustering blogs with collective wisdom. In: ICWE 2008: Proceedings of the 2008 Eighth International Conference on Web Engineering, pp. 336--339. IEEE Computer Society, Washington, DC, USA (2008)

BIOGRAPHIES

GOUSE MOHIDDIN KHAN

Faculty of Electrical &Electronics Engineering department BVCITS, Amalapuram

I VAMSI RAM
Faculty of Electrical &Electronics Engineering department BVCITS, Amalapuram