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Highlights

- 5 Level PWM Inverter
- Sensitive Component Models
- Diode Clamped Inverter
- Performance Analysis of EDFA

Discovering Thoughts, Inventing Future

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Clustering Based Load Flow for Three Phase Unbalanced Distribution System with Voltage Sensitive Component Models

By T. Murali Krishna, N.V. Ramana & S. Kamakshaiah
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Abstract - This paper presents a novel distribution power flow algorithm to estimate losses and analyze unbalanced distribution systems. An unbalanced distribution network is decomposed into clusters. The unbalanced laterals are solved using the backward/forward sweep method in each phase. The clustering of total network makes faster computation. The three phase modeling of all the distribution transformers, feeders, shunt capacitors and loads compile efficient algorithm. Load modeling is voltage dependent which makes up the load as voltage sensitive. The proposed method is tested on the IEEE 13 Node test system and the results are verified.

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CLUSTERING BASED LOAD FLOW FOR THREE PHASE UNBALANCED DISTRIBUTION SYSTEM WITH VOLTAGE SENSITIVE COMPONENT MODELS

Strictly as per the compliance and regulations of :

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T. Murali Krishna [α], N.V. Ramana [σ] & S. Kamakshaiah [ρ]

Abstract - This paper presents a novel distribution power flow algorithm to estimate losses and analyze unbalanced distribution systems. An unbalanced distribution network is decomposed into clusters. The unbalanced laterals are solved using the backward/forward sweep method in each phase. The clustering of total network makes faster computation. The three phase modeling of all the distribution transformers, feeders, shunt capacitors and loads compile efficient algorithm. Load modeling is voltage dependent which makes up the load as voltage sensitive. The proposed method is tested on the IEEE 13 Node test system and the results are verified.

Keywords : clustering, load flow, backward/forward sweep, radial distribution system, distribution system modeling, voltage sensitive components.

I. Introduction

Power flow analysis is essential for power system planning and operation. With the use of digital computing since 1960 and its rapid development, various power flow algorithms based on modern computing methods have been introduced. Certain applications, particularly in distribution automation and optimization require repeated load flow solutions. The load flow algorithm is used to determine the voltages and line flows for a large-scale power system from a given load and generation data. Conventionally, most of the distribution systems are radial or weakly meshed types. The power flow analysis in such distribution systems becomes more complex because of different characteristic features of distribution networks, such as radial structure and high R/X ratio [1]. Hence distribution system load flow analysis differs significantly from transmission systems. The single-phase power flow methods are normally used in the systems by neglecting unbalance in the system.

In distribution systems, the three-phase balanced statement cannot be practical. Therefore, a three-phase load flow algorithm with complete three-phase modeling is required. The radial distribution structure is also exploited in developing a fast and flexible radial power flow for unbalanced three-phase networks [2]. Several load flow algorithms specially designed for distribution systems have been proposed in the literature [3]–[10]. Those formulations can be divided into two categories. The first category was based on the distribution system general topology and uses the bus voltages as state variables to solve the load flow problem [3]. In this type, the most time-consuming load flow method is the Gauss implicit Y-Bus method [4], [5]. A fast decoupled load flow algorithm based on Newton Raphson, using rectangular voltage state variables is proposed which improves the execution time of the three-phase load flow [5]. The second category was based on the special network structures of distribution systems [6]-[8]. A compensation-based technique for weakly meshed distribution networks has been proposed [6]. By emphasizing on modeling of dispersed generation (PV nodes), unbalanced and distributed loads, and voltage regulators an algorithm was proposed [7]. Large weakly mesh connected distribution networks are solved by using an efficient tree-labeling technique which enhances computational efficiency as in [8]. The radial parts are solved by a two-step procedure in which the branch currents are first calculated (backward sweep) and then, the bus voltages are updated (forward sweep). Branch power flows rather than branch currents were later used in the improved version [9]. In recent times probabilistic load flows were also proposed considering distributed generation to obtain load flow variations with DG variation through backward forward sweep [10]. A decoupled method in which each phase is modeled in a decoupled way and therefore can be solved independently and the solution method is based on the Zbus Gauss approach, with implicit factorization of the Ybus matrix for each phase [11].

The algorithm proposed in this paper is basically a backward and forward sweep method. The approach used is based on clustering the total network which makes faster computation and also gives accurate results as it considers the three phase models of all the transformers, feeders, shunt capacitors and loads.

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II. Distribution System Modeling

a) Distribution line modeling

The feeder line modeling and the line parameters can be obtained by the method developed by Carson and Lewis [12].

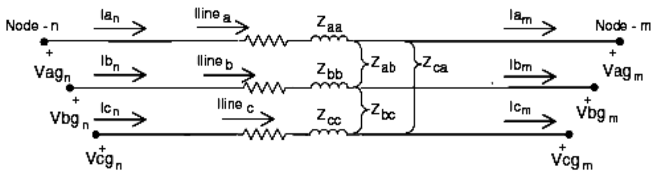

Figure 1 : Three phase transmission line model

Fig. 1 shows a three-phase line section between bus 'n'and 'm'. A 4 x 4 matrix, which takes into account the self and mutual coupling effects, can be expressed as (1)

$$\begin{bmatrix} V_n^a \\ V_n^b \\ V_n^c \\ V_n^n \end{bmatrix} = \begin{bmatrix} V_m^a \\ V_m^b \\ V_m^c \\ V_m^n \end{bmatrix} + \begin{bmatrix} Z_{nm}^{aa} & Z_{nm}^{ab} & Z_{nm}^{ac} & Z_{nm}^{an} \\ Z_{nm}^{ba} & Z_{nm}^{bb} & Z_{nm}^{bc} & Z_{nm}^{bn} \\ Z_{nm}^{ca} & Z_{nm}^{cb} & Z_{nm}^{cc} & Z_{nm}^{cn} \\ Z_{nm}^{na} & Z_{nm}^{nb} & Z_{nm}^{nc} & Z_{nm}^{nn} \end{bmatrix} \cdot \begin{bmatrix} I_{nm}^a \\ I_{nm}^b \\ I_{nm}^c \\ I_{nm}^n \end{bmatrix} \quad (1)$$

Applying Kron's reduction [12], the matrix dimension will reduce to 3 x 3, whereas the effects of the neutral or ground wire are still included in this model, as shown below in (2)

$$\left[Z_{br,nm}^{abc}\right] = \begin{bmatrix} Z_{nm}^{aa-n} & Z_{nm}^{ab-n} & Z_{nm}^{ac-n} \\ Z_{nm}^{ba-n} & Z_{nm}^{bb-n} & Z_{nm}^{bc-n} \\ Z_{nm}^{ca-n} & Z_{nm}^{cb-n} & Z_{nm}^{cc-n} \end{bmatrix} \quad (2)$$

For any phase failed to present, the corresponding row and column in this matrix will contain null-entries. The relationships between bus voltages and branch currents as shown in Fig. 1 can be expressed as (3)

$$\left[V_{br,nm}^{abc}\right] = \left[Z_{br,nm}^{abc}\right] \cdot \left[I_{br,nm}^{abc}\right] \quad (3)$$

I_{nm}^{abc} is the current vector through line between bus 'n' and 'm', can be equal to, the sum of the load currents of all the buses beyond line between bus 'n' and 'm' plus the sum of the charging currents of all the buses beyond line between bus 'n' and 'm', of each phase. Therefore, voltage of bus 'm' can be computed if bus 'n' voltage is known, as shown in (4).

$$\begin{bmatrix} V_j^a \\ V_j^b \\ V_j^c \end{bmatrix} = \begin{bmatrix} V_i^a \\ V_i^b \\ V_i^c \end{bmatrix} - \left[Z_{br,ij}^{abc}\right] \cdot \begin{bmatrix} I_{ij}^a \\ I_{ij}^b \\ I_{ij}^c \end{bmatrix} \quad (4)$$

b) Distribution Transformer Modeling

A three phase distribution transformer is represented by two blocks as shown in Figure 2.

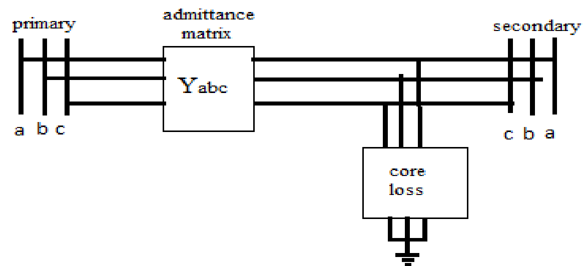

Figure 2 : Three phase transformer equivalent model

One block represents the per unit leakage admittance matrix Y^{abc} and the other block models the core loss as a function of voltage on the secondary side of the transformer. The core loss of a transformer is approximated by shunt core loss functions on each phase of the secondary terminal of the transformer. These core loss approximation functions are based on the results of EPRI load modeling research [13] which state that real and reactive power losses in the transformer core (P_c and Q_c) can be expressed as functions of the terminal voltage of the transformer. Transformer core loss functions represented in per unit at the system power base are expressed as below.

Pc= (KVA Rating/Base KVA)*A|V|2+B*Exp(C|V|2) (5)

Qc= (KVA Rating/Base KVA)*D|V|2+E*Exp(F|V|2) (6)

Where,

A=0.00267; B=0.734*10-9; C=13.5

D=0.00167; E=0.268*10-13; F=22.7

|V| is the voltage magnitude in per unit. It must be noted that the coefficients; A, B, C, D, E, and F are machine dependent constants. For the current work, core losses are represented by the functions and typical constants shown above.

$$Y_I = y_t \begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (7)$$

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$$Y_{II} = \frac{y_t}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \quad (8)$$

$$Y_{III} = \frac{y_t}{\sqrt{3}}\begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} \quad (9)$$

Where, y_t is the transformer leakage admittance. It is disclose to say that Y_{II} and Y_{III} are the singular matrix and this is valid if tap ratio is 1 on both sides of transformer else the coefficient of the matrix will as follows

$$Y_{I} = \frac{y_t}{\alpha^2};\ Y_{II} = \frac{y_t}{3\beta^2};\ Y_{III} = \frac{y_t}{\alpha\beta\sqrt{3}}$$

Where 'α' and 'β' are the primary and secondary side tap ratios.

The nodal admittance matrices for nine common connections of three-phase transformers were presented in [19] and tabulated in Table 1.

The nodal admittance matrix model for a three phase distribution transformer can be represented by

$$\begin{bmatrix} I_p \\ I_s \end{bmatrix} = \begin{bmatrix} Y_{pp} & Y_{ps} \\ Y_{sp} & Y_{ss} \end{bmatrix}\begin{bmatrix} V_p \\ V_s \end{bmatrix} \quad (10)$$

Where,

$Ip = [I^P_a\ I^P_b\ I^P_c]^T$ - Three-phase current injections on the primary side,

$I_s = [I^S_a\ I^S_b\ I^S_c]^T$ - Three-phase current injections on the secondary side,

$V_p = [V^P_a\ V^P_b\ V^P_c]^T$ - Three-phase voltages on the primary side,

$V_s = [V^S_a\ V^S_b\ V^S_c]^T$ - Three-phase voltages on the secondary side,

Y_{pp}, Y_{ps}, Y_{sp}, Y_{ss} are the sub matrices of the nodal admittance matrix of the transformer.

Table 1 : Transformer nodal Admittance matrix

Transformer Connection		Self Admittance		Mutual Admittance	
Primary	Secondary	Y_{pp}	Y_{ss}	Y_{ps}	Y_{sp}
GrY	GrY	Y_I	Y_I	$-Y_I$	$-Y_I$
GrY	Y	Y_{II}	Y_{II}	$-Y_{II}$	$-Y_{II}$
GrY	D	Y_I	Y_{II}	Y_{III}	Y^t_{III}
Y	GrY	Y_{II}	Y_{II}	$-Y_{II}$	$-Y_{II}$
Y	Y	Y_{II}	Y_{II}	$-Y_{II}$	$-Y_{II}$
Y	D	Y_{II}	Y_{II}	Y_{III}	Y^t_{III}
D	GrY	Y_{II}	Y_I	Y^t_{III}	Y_{III}
D	Y	Y_{II}	Y_{II}	Y^t_{III}	Y_{III}
D	D	Y_{II}	Y_{II}	$-Y_{II}$	$-Y_{II}$

c) Voltage Regulator Model

Voltage regulator is used to control the voltage in an amount up to 5 or 10 percent. In this paper, the voltage regulator is modeled by series impedance and a transformer with tap on secondary winding. That is, voltage regulator is treated as a three phase transformer.

d) Capacitor Modeling

Shunt capacitor banks are commonly used in distribution systems to help in voltage regulation and to provide reactive power support. The capacitor banks are modeled as constant susceptances connected in either star or delta. Similar to the load model, all capacitor banks are modeled as three-phase banks with the currents of the missing phases set to zero for single-phase and two-phase banks.

e) Load Models

A method for accommodating load compositions may vary by hour, day, season, etc. based on the usage. A pictorial representation showing percentages of the total load is used and is termed as a "load window" as illustrated in Fig. 3.

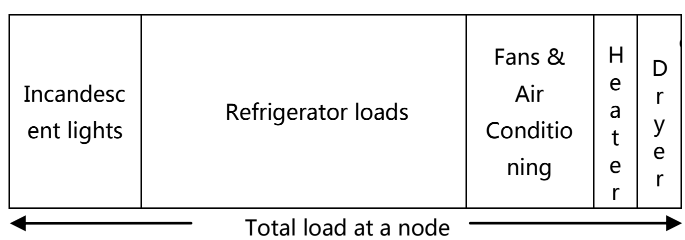

Figure 3 : Typical Load Window at a node

The load model equations from [7] are used and the proportions of the loads are given in a arbitrary way for solving the system. Loading of the system is done with the standard loadings but in the ratio load equations considered i.e., the load equations are assumed instead of total assumption of the single load. For example, if the load at a node is 100 KW then 46% (46 KW) of the load is assumed as consumed by refrigerator loads, 22% (22 KW) by fans and air conditioned loads, 18% (18 KW) by the incandescent lights, 8% (8 KW) by dryer loads and 6% (6 KW) by heaters.

i. *Wye Connected Loads*

The notation for the specified complex powers and voltages are as follows:

$$Phase-i = |S_i|\angle\theta_i = P_i + jQ_i and |V_{in}|\angle\delta_i \quad (11)$$

Where, i- represents *a, b and c Phases.*

a. *Constant Power Load*

The line currents for constant real and reactive power loads (PQ loads) are given by:

$$\begin{aligned} IL_a &= \left(\frac{S_a}{V_{an}}\right)^* = \frac{|S_a|}{|V_{an}|}\angle(\delta_a - \theta_a) = |IL_a|\angle\alpha_a \\ IL_b &= \left(\frac{S_b}{V_{bn}}\right)^* = \frac{|S_b|}{|V_{bn}|}\angle(\delta_b - \theta_b) = |IL_b|\angle\alpha_b \\ IL_c &= \left(\frac{S_c}{V_{cn}}\right)^* = \frac{|S_c|}{|V_{cn}|}\angle(\delta_c - \theta_c) = |IL_c|\angle\alpha_c \end{aligned} \quad (12)$$

Here, line-to-neutral voltages will change during each iteration until convergence is achieved.

b. *Constant Impedance Load*

The constant impedance load is first determined from the specified complex power and assumed line-to-neutral voltages:

$$\begin{aligned} Z_a &= \frac{|V_{an}|^2}{S_a^*} = \frac{|V_{an}|^2}{|S_a|}\angle\theta_a = |Z_a|\angle\theta_a \\ Z_b &= \frac{|V_{bn}|^2}{S_b^*} = \frac{|V_{bn}|^2}{|S_b|}\angle\theta_b = |Z_b|\angle\theta_b \\ Z_c &= \frac{|V_{cn}|^2}{S_c^*} = \frac{|V_{cn}|^2}{|S_c|}\angle\theta_c = |Z_c|\angle\theta_c \end{aligned} \quad (13)$$

The load currents as a function of the constant load impedances are given by:

$$\begin{aligned} IL_a &= \frac{V_{an}}{Z_a} = \frac{|V_{an}|}{|Z_a|}\angle(\delta_a - \theta_a) = |IL_a|\angle\alpha_a \\ IL_b &= \frac{V_{bn}}{Z_b} = \frac{|V_{bn}|}{|Z_b|}\angle(\delta_b - \theta_b) = |IL_b|\angle\alpha_b \\ IL_c &= \frac{V_{cn}}{Z_c} = \frac{|V_{cn}|}{|Z_c|}\angle(\delta_c - \theta_c) = |IL_c|\angle\alpha_c \end{aligned} \quad (14)$$

In this model the line-to-neutral voltages will change during each iteration, but the impedance computed in the equation will remain constant.

c. *Constant Current Load*

In this model the magnitudes of the currents are computed according to Constant power equations and are then held constant while the angle of the voltage (δ) changes, resulting in a changing angle on the current so that the power factor of the load remains constant:

$$\begin{aligned} IL_a &= |IL_a|\angle(\delta_a - \theta_a) \\ IL_b &= |IL_b|\angle(\delta_b - \theta_b) \\ IL_c &= |IL_c|\angle(\delta_c - \theta_c) \end{aligned} \quad (15)$$

ii. *Delta Connected Loads*

As similar to wye connected loads delta can also expressed as

$$\begin{bmatrix} IL_q^a \\ IL_q^b \\ IL_q^c \end{bmatrix} = \begin{bmatrix} \left(\frac{SL_q^{ab}}{V_q^{ab}}\right)^* * |V_q^{ab}|^n - \left(\frac{SL_q^{ca}}{V_q^{ca}}\right)^* * |V_q^{ca}|^n \\ \left(\frac{SL_q^{bc}}{V_q^{bc}}\right)^* * |V_q^{bc}|^n - \left(\frac{SL_q^{ab}}{V_q^{ab}}\right)^* * |V_q^{ab}|^n \\ \left(\frac{SL_q^{ca}}{V_q^{ca}}\right)^* * |V_q^{ca}|^n - \left(\frac{SL_q^{bc}}{V_q^{bc}}\right)^* * |V_q^{bc}|^n \end{bmatrix} \quad (16)$$

n=0, for constant power loads

n=1, for constant current loads

n=2, for constant impedance loads

III. Solution Methodology

The solution procedure starts using a clustering technique applied to a radial distribution system as shown in figure 4. The basic rules followed for cluster formation are:

- There should be no further bifurcation in the cluster.
- The cluster will start from a branch but not from the node (except first cluster).
- The cluster will have only one parent node and one terminal node.

The clusters are solved by following different notations as shown in Table 2.

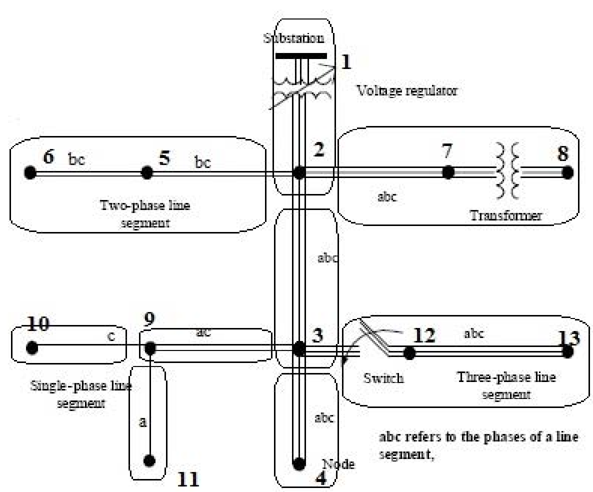

Figure 4 : Cluster formation of the test system

Table 2 : Cluster Formation

Cluster number	Parent node	Terminal node	Initial branch	Start node	End node
I	1	2	1	2	--
II	2	3	2	3	--
III	2	8	6	7	8
IV	2	6	4	5	6
V	3	4	3	4	4
VI	3	9	8	9	--
VII	3	13	11	12	13
VIII	9	10	9	10	10
IX	9	11	10	11	11

After the clusters are formed currents are determined in the backward direction i.e., the evaluation starts from the last cluster. Each cluster is passed to the backward sweep function and then the current through each branch is determined. Then the last cluster i.e., here 9th cluster is passed through the backward sweep it checks whether the terminal node of the cluster is end node or not, if it is the end node then it is taken as the current that flowing out of the node is zero and the current at that nodes is calculated by using the equations given above for respective load type. If there is no transformer in the branch, the branch current is determined by using equation (17).

$$I_B^{abc}(i, k-1) = I_N^{abc}(i, k) + I_B^{abc}(i, k) \qquad (17)$$

Where i = cluster number; k = node number

If the terminal node is not the end node then the current through that cluster terminal branch is given by equation (18).

$$I_B^{abc}(i, k-1) = I_N^{abc}(i, k) + I_B^{abc}(i+1, x) + I_B^{abc}(i+2, y) \qquad (18)$$

Else, if there is a transformer then the core power loss of the transformer is added as the load to node that connected to secondary of the transformer and node current is determined.

$$I_s^{abc}(i,k-1) = I_N^{abc}(i, k) + I_B^{abc}(i+1, x) + I_B^{abc}(i+2, y) \qquad (19)$$

The intermediate primary voltages $V_{p,m}$ are only to calculate the power injections on the primary side. These are the primary voltages calculated in backward sweeps, which can be found by

$$V_{p,m} = [Yps]^{-1}[I_{ss}] \qquad (20)$$

Where,

$$[I_{ss}] = [I_s] - [Yss]*[Vs] \qquad (21)$$

If Yps is singular, two of the three linearly dependent equations in (20) can be solved simultaneously with a third equation, which is given by

$$V_{p,m}^{a} + V_{p,m}^{b} + V_{p,m}^{c} = 0 \qquad (22)$$

But this will give only the sum of positive and negative sequence terms for zero sequence we

$$V_p^0 = \frac{V_p^a + V_p^b + V_p^c}{3} \qquad (23)$$

Thus by adding positive negative and zero sequence we get the total intermediate primary

$$V_{p,m} = \begin{bmatrix} V_{p,m}^{a(1+2)} \\ V_{p,m}^{b(1+2)} \\ V_{p,m}^{c(1+2)} \end{bmatrix} + \begin{bmatrix} V_p^0 \\ V_p^0 \\ V_p^0 \end{bmatrix} \qquad (24)$$

The power injections on the primary side can be calculated by

$$V_{p,m} = [Yps]^{-1}[I_{ss}] \qquad (25)$$

Where,

$$[I_{ss}] = [I_s] - [Yss]*[Vs] \qquad (26)$$

Then the primary side current injection is calculated as

$$I_p = \left[\left(\frac{S_p^a}{V_p^a} \right) \left(\frac{S_p^b}{V_p^b} \right) \left(\frac{S_p^c}{V_p^c} \right) \right] \qquad (27)$$

If the end node is equal to terminal node

$$I_B^{abc}(i, k-1) = I_N^{abc}(i, k) + I_B^{abc}(i, k) + I_p \qquad (28)$$

Else

$$I_B^{abc}(i,k-1) = I_N^{abc}(i,k) + I_B^{abc}(i+1,x) + I_B^{abc}(i+2,y) + I_p \qquad (29)$$

Where x, y are the branches that connect the terminal node of the cluster.

While calculating the branch currents, the proposed software checks the node numbers with the nodes stored in the array. If there is no transformer in the before branch then the voltages at the nodes are given by equation (30) if the node is not the start node of the cluster.

$$V_N^{abc}(i,k) = V_N^{abc}(i,k-1) + I_B^{abc}(i,k-1) * Z^{abc-n}(i,k-1) \qquad (30)$$

If the node is the start node then the voltage is given by equation (31)

$V_N^{abc}(i,k)=V_N^{abc}(i-1,k-1)+I_B^{abc}(i,k-1)*Z^{abc-n}(i,k-1)$ (31)

If there is transformer in the previous branch then we calculate the voltage of the node that connected to secondary of the transformer as

$$V_s = Y_{ps}^{-1}\left[I_p - Y_{pp}V_p\right] \tag{32}$$

Here, Ip is similar to that of calculated in backward sweep of that iteration.

If Y_{ps} is singular then we have to follow the similar approach that stated for $V_{p,m}$ calculation by which we get sum of positive and negative sequence values, for the zero sequence we use following expression.

$$V_s^0 = \frac{\left(V_{s,m}^a + V_{s,m}^b + V_{s,m}^c\right)}{3} \tag{33}$$

Where, $[V_{s,m}] = [Yss^{-1}][I_s\text{-}YspV_p]$.

If Y_{ss} is also singular then V_s^0 is entirely a function of downstream grounding conditions. If the downstream sub network contains no zero sequence current paths then V_s^0 is zero. The voltage of the node that connected to the secondary is given by below expression

V_N^{abc} (i, k)=Vs^{abc} (34)

The power losses in the system are given by

L_P^{abc} (i, k) = $[I_B^2]^{abc}$ (i, k) $*R^{abc-n}$ (i, k (35)

L_q^{abc} (i,k)=$[I_B^2]^{abc}$ (i, k) $*X^{abc-n}$ (36)

After computing the voltages at all nodes, convergence of the solution is checked. As per the method proposed in this paper, the solution converges after successive iterations if the maximum difference in voltage magnitude (ΔV_{max}) is equal to 0.00001.

IV. Algorithm

Step 1 : Active and Reactive loads at each node are to be given in the proportions of the load models, based on the load window in the chronological order.

Step 2 : Branch impedance values for each branch along with its starting and ending nodes is to be given in the chronological order.

Step 3 : Cluster the branches to implement backward forward sweep methodology

Step 4 : Based on the number of times a particular node repeats itself as starting node, the number of clusters emanating from that particular node is obtained.

Step 5 : After detection of parent node by traversing through sending end node, final node of cluster is obtained at the end of chronological order.

Step 6 : By implementing similar steps to the entire system all cluster sets formed are arranged as an array of structures for better computational ability.

Step 7 : Each structure element tracks the requisite data to calculate voltage and current profiles of the constituents of a cluster.

Step 8 : Based on the cluster order, backward sweep is executed which involves calculation of branch currents from voltage profile of previous iteration or initial conditions.

Step 9 : Forward sweep is executed in the forward direction which updates the voltages and the loads based on the deviation of voltage as per load models

Step 10 : Repeat the process until the system is converged.

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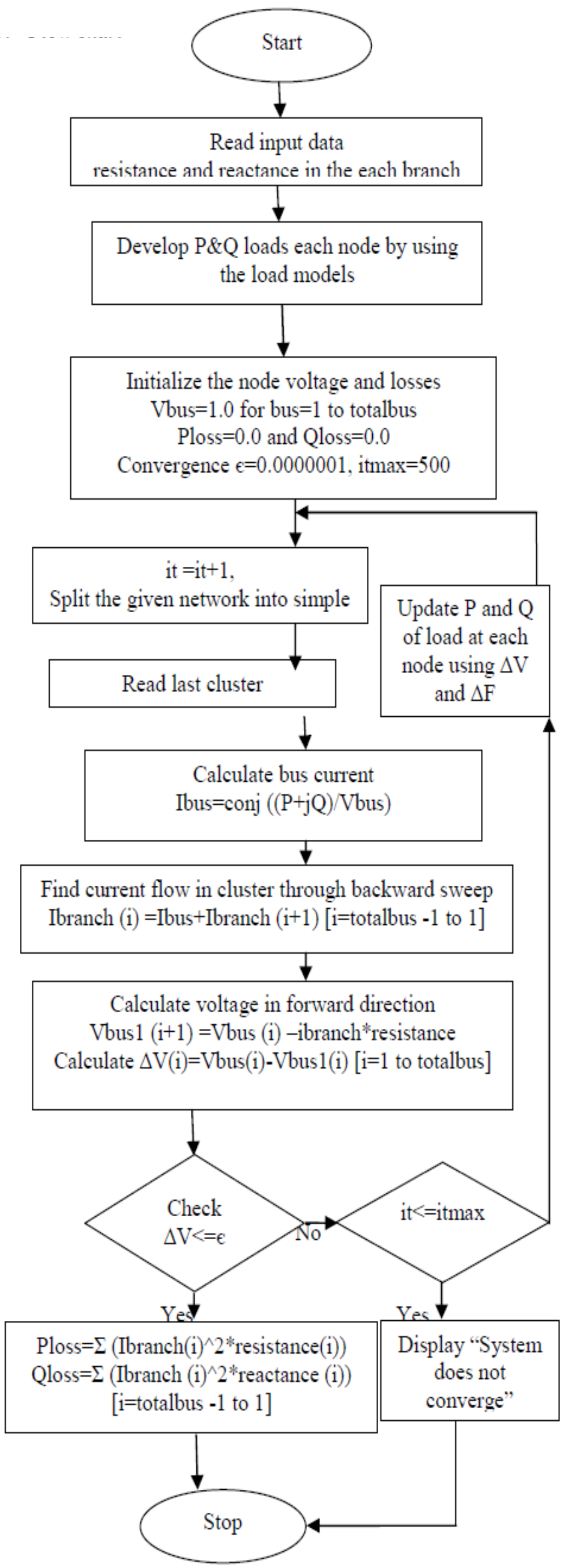
V. Flow Chart



VI. Results

The proposed method is applied to an IEEE-13 Bus unbalanced Radial Distribution System and the results are tabulated as in Table 3. The results are verified with the standard test results [18]. The results are also compared with the Node Admittance method proposed in [15] as shown in Table 4 . Both methods were executed on a Microcomputer with 2.6 GHz Intel i5 Processor.

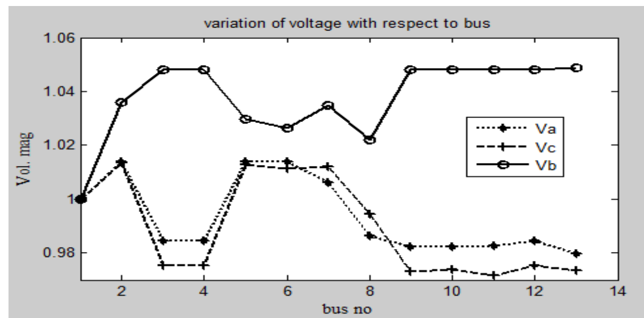


Figure 5 : Voltage variation with respect to each bus

Table 3 : Voltage magnitude and angle at each bus

Bus no	Va Mag	Va Angle	Vb Mag	Vb Angle	Vc Mag	Vc Angle
1	1.0	0	1.0	-120	1.0	120
2	1.014	-2.86	1.036	-122.06	1.013	117.54
3	0.984	-5.69	1.047	-122.77	0.975	115.82
4	0.984	-5.69	1.047	-122.77	0.975	115.82
5	1.014	-2.86	1.029	-122.14	1.012	117.58
6	1.014	-2.86	1.026	-122.26	1.011	117.61
7	1.006	-3.03	1.034	-122.86	1.012	117.51
8	0.986	-3.57	1.021	-122.36	0.994	116.93
9	0.982	-5.74	1.047	-122.77	0.973	115.68
10	0.982	-5.74	1.047	-122.77	0.973	115.78
11	0.982	-5.63	1.047	-122.77	0.971	115.62
12	0.984	-5.69	1.047	-122.77	0.975	115.82
13	0.979	-5.94	1.048	-122.92	0.973	115.84

Table 4 : Comparison of losses and time elapsed between Node Admittance and proposed method

	Node Admittance Method			Proposed Method		
	A (ph)	B (ph)	C (ph)	A (ph)	B (ph)	C (ph)
KW Loss	39.87	-4.98	76.89	40.566	-3.76	70.09
KVAR Loss	152.8	42.63	129.0	154.56	48.33	130.9
Time	0.002057 Seconds			0.001834 Seconds		

VII. Conclusion

The load flow analysis of a three phase unbalanced radial distribution system has been discussed by considering the entire distribution system modeling. An unbalanced radial distribution network is decomposed into a main three phase circuit and unbalanced laterals. An improved load flow algorithm has been used which reduces the time and iterations for the convergence. The advantage of the proposed formulation is that a complicated distribution network is decomposed to many sub systems. By considering the load models this load flow can also be easily applicable to real time system with efficient data and calculations.

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Closed Loop Control of Three-Level Diode Clamped Inverter Fed IPMSM with Different Modulation Techniques

By G. Sree Lakshmi, S. Kamakshaiah & G. Tulasi Ram Das
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GJRE-F Classification : FOR Code: 090699, 020404

CLOSED LOOP CONTROL OF THREE-LEVEL DIODE CLAMPED INVERTER FED IPMSM WITH DIFFERENT MODULATION TECHNIQUES

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G. Sree Lakshmi [α], S. Kamakshaiah [σ] & G. Tulasi Ram Das [ρ]

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I. Introduction

Electric motors have been developed over 100 years ago. Till last decades of 20th century DC motor drives dominated the field of variable speed drives because of their easier controllability. At the end of the 1960s K. Hasses, introduced the field oriented control of AC motor from then onwards DC drives declined because of several advantageous of AC motors such as much cheaper, less maintenance ,no mechanical commutator, and wider speed range [1]-[3]. Presently induction motor is the prominent motor used for all speed ranges. But however, synchronous motors are replacing them because of many attractive features compared to induction motors. The use of DC excited synchronous motor has been limited to generation and other high power applications. For medium power range drives due to higher price and more complex structure they cannot compete with induction motors [4]-[6]. If the DC excited rotor winding is replaced by permanent magnets, then the structure is greatly simplified, no excitation winding is required which ensures higher efficiency because there are no current circuits in the rotor due to which copper losses are reduced and also cooling is much easier compared to induction motor. The use of modern rare-earth magnetic materials enables high flux densities and facilitates the construction of motors with unsurpassed power density [5].

Permanent magnets can be manufactured in many shapes, depending on the design PM electric machines can be first classified into two groups, namely, PMDC and PMAC. PMDC machines are similar to the conventional DC commutator machines except the field is generated by permanent-magnets located in the rotor. The PMAC machines can be further classified into trapezoidal and sinusoidal types. The trapezoidal PMAC machines also called “brushless DC motors” (BLDCM) were developed because of the simple control of those machines. Sinusoidal PMAC machines are classified into two groups with respect to their rotor structures as; Surface Mount Permanent Magnet (SMPM) synchronous motors and Interior Permanent Magnet (IPM) synchronous motors. SMPM motors have the permanent magnets mounted on the outer surface of the rotor, and IPM motors have the permanent magnets buried in the rotor core. IPM motors are newly developed motors with high torque density, high efficiency characteristics and additionally provide field weakening operation, which is impossible with the SMPM motors [5]-[8]. To improve the efficiency and performance of the drive, IPM motors are preferred in the industrial applications because they have the advantage of providing position control loop with accuracy, without a shaft encoder as in case of induction motors. PMSM can be accurately controlled by using vector control in which field oriented theory is used to control current, voltage and space vectors of magnetic flux. Filed oriented control is a basic method in which real- time control of torque variations, rotor

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mechanical speed and phase currents to avoid current spikes during transient phases is possible [7]-[10].

To optimize the drive performance extending the speed range flux weakening control using number of control schemes have been presented[1]-[10]. However, drive performance, particularly the torque speed characteristics, strongly correlates with the employed modulation strategies. The basic modulation technique is a pulse width modulation (PWM) which not only reduces harmonic distortion but also gives constant switching frequency operation of the inverters. After having a detailed survey on various PWM techniques [16] it is concluded that space vector pulse width modulation (SVPWM) technique gives good performance. Switching pulse generation in SVPWM technique is given in [17]. SVPWM gives good performance, but however the complexity involved is more in calculating angle and sector. To reduce the complexity involved in SVPWM, a novel modulation technique named Unified voltage modulation or carrier based space vector pulse width modulation (CBSVPWM) is described using the concept of effective time[16]-[20]. By using this method the inverter output voltage is directly synthesized by the effective times and the voltage modulation task can be greatly simplified. The actual gating signals for each inverter arm can be easily deduced as a simple form using the effective time relocation algorithm. To meet medium and high power applications, multilevel inverters are becoming popular [11]-[13]. The neutral-point-clamped three-level inverter obtains growing interesting in high voltage and power applications. Compared with the conventional two-level inverter, the three-level inverter has demonstrated significant advantages [14][15]. As the level increases, the complexity involved in the modulation techniques also increases. In this paper a three-level diode clamped inverter fed IPMSM drive has simulated using this new CBSVPWM technique. Closed loop torque and speed control is studied using FOC with PI controller.

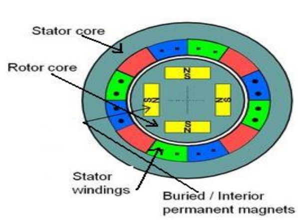

Figure 1 : Interior Permanent Magnet Motor

II. IPMSM

The voltage equation of a synchronous motor on the d-q axis component is represented as following.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} R + pL_d & -\omega L_q \\ \omega L_d & R + pL_q \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} 0 \\ \omega \varphi_a \end{bmatrix} \qquad (1)$$

Where,

φa : Armature flux linkages due to permanent magnets along the d-axis

i_d, i_q : Armature currents components of d&q- axis

V_d, V_q: Armature voltage components of d & q- axis Ld, L_q: d and q axis inductances

R : Armature winding resistance

ω : Angular velocity

p : p=d/dt

Transforming (1) into $\alpha - \beta$ fixed coordinate,

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \begin{bmatrix} R + pL_\alpha & pL_{\alpha\beta} \\ pL_{\alpha\beta} & R + pL_\beta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} + \omega_{re} K_E \begin{bmatrix} -sin\theta_{re} \\ cos\theta_{re} \end{bmatrix} \qquad (2)$$

Where

$$L_\alpha = L_0 + L_1 cos2\theta, \quad L_\beta = L_0 - L_1 cos2\theta,$$
$$L_0 = (L_d + L_q)/2, \quad L_1 = (L_d - L_q)/2 \qquad (3)$$
$$L_{\alpha\beta} = L_1 sin2\theta$$

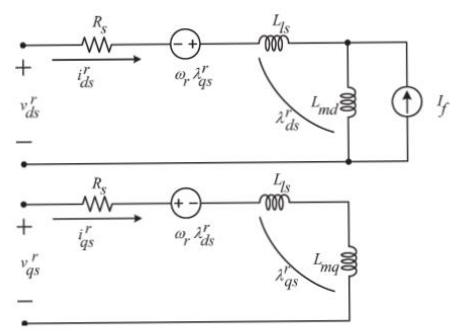

Figure 2 : Equivalent circuit of IPMSM in d and q axis

An IPMSM is constructed with permanent magnets embedded in the rotor core. This makes the rotor a salient pole and both magnetic torque and reluctance torque can be utilized.

The output torque equation of IPMSM is given by:

$$T = P_n\{\varphi_a i_q + (L_d - L_q) i_d i_q\}$$
$$= P_n\{\varphi_a i_a cos\beta + 1/2(L_d - L_q) i_a^2 sin2\beta\} \qquad (4)$$

The output torque T depends on the interlinkage flux φa and the difference between the d- and q- axis inductance L_d- L_q

Where,

P_n= No. of poles pairs

I_a= Armature current amplitude,

$$I_a = \sqrt{i_q^2 + i_d^2} \qquad (5)$$

β=Armature current lead angle from the q-axis

The first term in the torque equation (4) represents the magnetic torque generated from the interlinkage flux of the permanent magnets, the second term represents the reluctance torque generated by the differences between d-axis and q-axis inductance.

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The motor drive system dynamics is also represented by

$$T_e = T_L + B\omega_m + Jp\omega_m \quad (6)$$

Where T_L and ω_m are load torque and motor speed respectively.

III. Control Methods

To run at different speeds, synchronous motors have to be driven by a Variable Frequency Drive (VFD). Electric motors control methods can be divide into two main categories depending of what quantities they control. Scalar Control controls only magnitudes, whereas the Vector Control controls both magnitude and angles. Scalar control is by V/f whereas vector control is possible by Field Oriented control (FOC). Scalar control is the simplest method to control a PMSM, in which frequency is kept constant depending on the speed required and there exist a relationship between voltage and current. No control over angles is utilized, hence the name scalar control. The method uses an open-loop control approach without any feedback of motor parameters or its position. This makes the method easy to implement and with low demands on computation power of the control hardware, but its simplicity also comes with some disadvantages. Vector control allows both magnitude and phase angle control by which higher dynamic performance of the drive system is possible.

a) Field Oriented Control (FOC)

The goal of the Field Oriented Control is to control the direct- and quadrature-axis current id and iq to achieve required torque. By controlling id and iq independently we can achieve a Maximum Torque per Ampere ratio to minimize the current needed for a specific torque, which increases the motor efficiency.

For a non-salient machine, control technique can be easily implemented because Ld=Lq and produces only one torque i.e electromechanical torque, Whereas for salient machine Ld≠Lq therefore the control is a bit more difficult to implement since the motor produces both electromechanical and reluctance torque.

For non-salient pole machine the torque equation is given by:

$$T_e = \frac{3}{2}\frac{P}{2}\left[\lambda_{pm} I_{sq}\right] \quad (7)$$

From the above equation the torque producing current is along the quadrature -axis. To reach maximum efficiency, the torque per ampere relationship should be maximum. This can be easily obtained by keeping the direct-axis current to zero at all times. The control systems reference currents id* and iq* is gives as:

$$i_q^* = \frac{T_e^*}{\frac{3}{2}\frac{P}{2}\lambda_{pm}} \quad (8)$$

$$i_d^* = 0 \quad (9)$$

For salient pole machine the direct- and quadrature axis inductances are unequal and for the steady state operation the torque equation is given as:

$$T_e = \frac{3}{2}\frac{P}{2}\left[\lambda_{pm} I_{sq} - \left(L_q - L_d\right) I_{sd} I_{sq}\right] \quad (10)$$

From the above equation there are two terms affecting the torque production, the electromechanical torque

$$\frac{3}{2}\frac{P}{2}\lambda_{pm} I_{sq} \quad (11)$$

And the reluctance torque is

$$\frac{3}{2}\frac{P}{2}\left(L_q - L_d\right) I_{sd} I_{sq} \quad (12)$$

b) Closed loop PI control using FOC

The block diagram of closed loop PI control using FOC to investigate the speed and torque control with different modulation techniques such as SPWM, SVPWM and CBSVPWM for a voltage source three-level diode clamped inverter fed IPMSM is presented in fig. 3. Every time the currents and the voltages are measured and transformed into α-β reference frame. The currents are further converted into d-q frame using Park's Transformation. The reference speed is compared with the motor speed and the

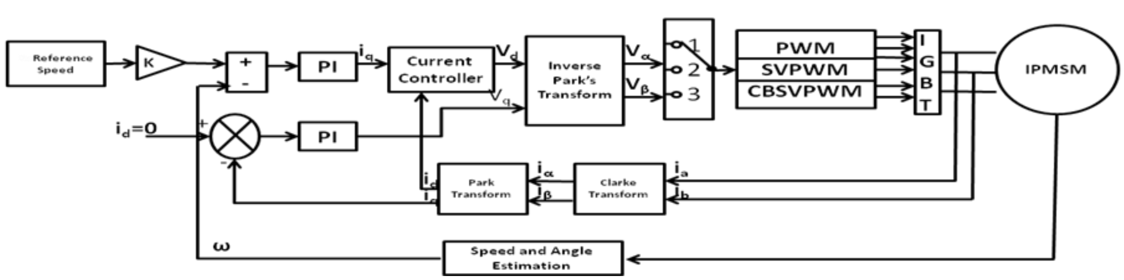

Figure 3 : Block diagram of closed loop control of three-level diode-clamped inverter using FOC with different modulation techniques

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error is given to the PI controller. The output of the PI controller is taken as quadrature axis current iq. The reference direct-axis current id =0 is considered. The reference direct-axis current is compared with transformed current and given to another PI controller. The Output of PI controllers goes to current controller where the voltages Vd and Vq can be generated. From these voltages, reference voltages can be generated using different modulation techniques. The Switch is used to carry out three modulation techniques. The reference waves which are generated compared with the triangular waves and the pulses are obtained which are given to the 12 IGBT's of the three level diode clamped inverter. The output of the inverter is given to the IPMSM to control the speed and torque of the motor.

IV. Modulation Techniques

a) *Pulse Width Modulation*

The basic control method in power electronics is the Pulse-width modulation (PWM). Except some resonant converters, majority of power electronic circuits are controlled by PWM signals of various forms. In this technique the duty ratio of a pulsating wave-form is controlled by another input waveform. The ON and OFF times of the switches can be obtained by the intersections between the reference voltage waveform and the carrier waveform. By changing the duty ratio of the switches the speed of the motor can be changed. The longer the pulse is closed higher the power supplied to the load. The change of state between closing (ON) and opening (OFF) is rapid, so that the average power dissipation is very low compared to the power being delivered.

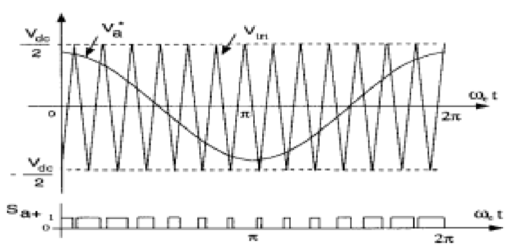

Figure 4 : Pulse width modulation

The theoretically zero rise and fall time of an ideal PWM waveform represents a preferred way of driving modern semiconductor power devices The rapid rising and falling edges ensure that the semiconductor power devices are turned on or turned off as fast as practically possible to minimize the switching transition time and the associated switching losses.

b) *Space Vector Pulse Width Modulation*

The SVPWM technique for three-level inverter consists of 27 switching states out of which there are 24 active states and 3 zero states at the center of the hexagon. If the triangle sector is defined by vector V_x, V_y, V_z, then V* can be synthesized by V_x, V_y, and V_z. Assuming the duration of vector Vx, Vy, and Vz are Tx, Ty, and Tz respectively and $T_x+T_y+T_z$ = Ts, where Ts is switching period. Then X, Y and Z can be defined as the

$$X = T_x/Ts \quad Y=T_y/Ts \quad Z = T_z/Ts \tag{13}$$

Based on the principle of vector synthesis, the following equations can be written as

$$X+Y+Z=1 \qquad V_x{}^*X + V_y{}^*Y + V_z{}^*Z = V^* \tag{14}$$

The modulation ratio of three-phase three-level inverter is represented as follows

$$m = |V^*|/(2/3Vd) = 3|V^*|/2Vd \tag{15}$$

The boundaries of modulation ratio are Mark1, Mark2, and Mark3.

$$\begin{aligned} Mark_1 &= (\sqrt{3/2}) / (\sqrt{3}\cos(\theta) + \sin(\theta)) \\ Mark_2 &= (\sqrt{3}/2)/(\sqrt{3}\cos(\theta)-\sin(\theta)); \quad \theta \le \pi \\ &= (\sqrt{3}/4) / \sin(\theta) \quad \pi/6 < \theta \le \pi/3 \\ Mark_3 &= \sqrt{3} / (\sqrt{3}\cos(\theta) + \sin(\theta)) \end{aligned} \tag{16}$$

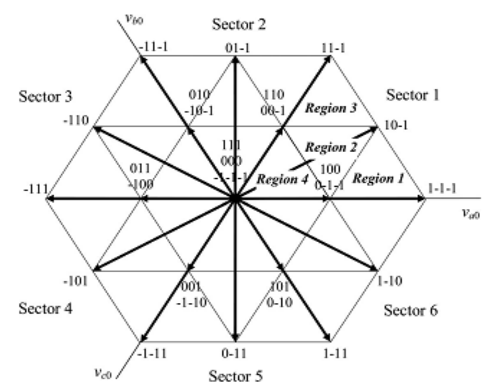

Figure 5 : Space vector hexagon for three-level inverter

Case 1 : When the modulation ratio m<Mark1, the rotating voltage vector V*is in sector D1, V* is synthesized by V0, V1, and V2

$$1/2X + 1/2[\cos(\pi/3)\, Y + j\sin(\pi/3)]\, Y = m[\cos(\theta) + j\sin(\theta)]$$

Using above equations, we can obtain X, Y, and Z as follows:

$$\begin{aligned} X &= 2m[\cos(\theta) - \{\sin(\theta)/\sqrt{3}\}] \\ Y &= m*4*\sin(\theta)/\sqrt{3} \\ Z &= 1-2*m[\cos(\theta) + (\sin(\theta))/\sqrt{3}] \end{aligned} \tag{17}$$

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Case 2 : When (Mark1 < m < Mark2), V* is in sector D1, V* can be synthesized by V1, V2, and V7 and the corresponding X, Y, and Z are:

$$X = 1- m*4*\sin(\theta)/\sqrt{3}$$

$$Y = 1- 2*m. [\cos(\theta) - (\sin(\theta))/\sqrt{3}] \quad (18)$$

$$Z = -1 + 2*m [\cos(\theta) + (\sin(\theta))/\sqrt{3}]$$

Case 3 : When (Mark2<m<Mark3) and (0<θ<π/6), V* is in sector D13. V1, V13, and V7 are selected to synthesize V*.

$$X = -1 + 2*m [\cos(\theta) - (\sin(\theta))/\sqrt{3}]$$

$$Y = m*4*\sin(\theta)/\sqrt{3} \quad (19)$$

$$Z = 2-2*m [\cos(\theta) + (\sin(\theta))/\sqrt{3}]$$

Case 4 : When (Mark2 < m < Mark3) and (π/6<θ<π/3), V* is in sector D14. Vectors V2. V7, and V14 will be employed to generate the required voltage. X, Y, and Z can be expressed as follows:

$$X = 2*m [\cos(\theta) - (\sin(\theta))/\sqrt{3}]$$

$$Y = -1+ m*4\sin(\theta)/\sqrt{3} \quad (20)$$

$$Z = 2-2*m [\cos(\theta) + (\sin(\theta))/\sqrt{3}]$$

When the reference vector falls into the others major sectors, similar argument can be applied. Replacing θ by θ-60, θ-120, θ-180, θ-240, and θ-300 respectively, the calculation of the entire coordinate plane can be established.

c) *Carrier Based Space Vector Pulse Width Modulation*

Carrier based SVPWM allow fast and efficient implementation of SVPWM without sector determination. The technique is based on the duty ratio profiles that SVPWM exhibits. By comparing the duty ratio profile with a higher frequency triangular carrier the pulses can be generated, based on the same arguments as the sinusoidal pulse width modulation [8]. Figure 6 shows the switching states of sector 1 at different times during two sampling intervals. TS denote the sampling time and Teff denotes the time duration in which the different voltage is maintained. Teff is called the "effective time". For the purpose of explanation, an imaginary time value will be introduced as follows:

$$T_{xs} = \frac{T_S}{V_{dc}} \quad (21)$$

V_{as}^*, V_{bs}^* and V_{cs}^* are the A-phase, B -phase, and Cphase reference voltages, respectively. This switching time could be negative in the case where negative phase voltage is commanded.

Therefore, this time is called the "imaginary switching time".

$$T_{xs} = \frac{T_s}{V_{dc}}$$

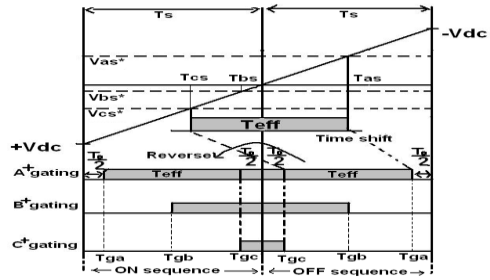


Figure 6 : Actual gating time generation for CBSVPWM

Now, the effective time can be defined as the time duration between the minimum and the maximum value of three imaginary times, as given by

$$Teff = Tmax-Tmin \quad (22)$$

$$Tmin = \min(Tas,Tbs,Tcs) \quad (23)$$

$$Tmax = \max(Tas,Tbs,Tcs) \quad (24)$$

When the actual gating signals for power devices are generated in the PWM algorithm, there is one degree of freedom by which the effective time can be relocated anywhere within the sampling interval.

Therefore, a time-shifting operation will be applied to the imaginary switching times to generate the actual gating times (T_{ga}, T_{gb}, T_{gc}) for each inverter arm, as shown in Fig. 6. This task is accomplished by adding the same value to the imaginary times as follows:

$$Tga=Tas+Toffset \quad (25)$$

$$Tgb=Tbs+Toffset \quad (26)$$

$$Tgc=Tcs+Toffset \quad (27)$$

Where T_{offset} is the 'offset time'

This gating time determination task is only performed for the sampling interval in which all of the switching states of each arm go to 0 from 1. This interval is called the "OFF sequence". In the other sequence, it is called the "ON sequence."

In order to generate a symmetrical switching pulse pattern within two sampling intervals, the actual switching time will be replaced by the subtraction value, with sampling time as follows:

$$Tga=Ts-Tga \quad (28)$$

$$Tgb=Ts-Tgb \quad (29)$$

$$Tgc=Ts-Tgc \quad (30)$$

V. Three Level Diode Clamped Inverter

Multilevel inverters are becoming increasingly popular for high power applications, because their switched output voltage harmonics can be considerably reduced by using several voltage levels while still switching at the same frequency.

As well, higher input DC voltages can be used since semiconductors are connected in series for multilevel inverter structures, and this reduces the DC voltage each device must withstand. Among the multilevel topologies, the three-level diode clamped topology has been widely used.

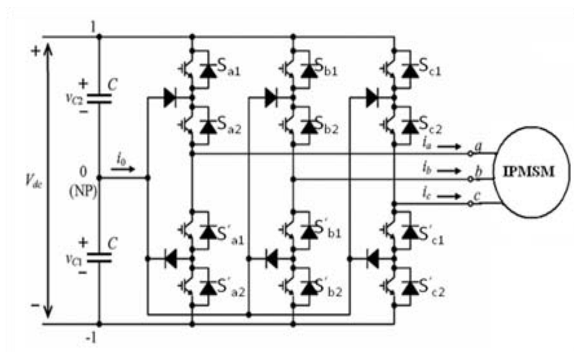


Figure 7 : Three-level diode clamped inverter fed IPMSM

Table 1 : Switching sequences for three level diode clamped inverter

Output Voltage	Switching Sequence			
	S_{a1}	S_{a2}	S_{a1}'	S_{a2}'
0	0	1	1	0
$V_{dc}/2$	1	1	0	0
$-V_{dc}/2$	0	0	1	1

Figure 7 shows the three-level diode clamped inverter fed to IPMSM drive, where only one DC source V_d is needed. Two capacitors are used to split the DC voltage and provide a neutral point Z.

The inverter leg A is composed of four active switches S_{a1}, S_{a2}, S_{a1} and S_{a2} ' with four antiparallel diodes D_1 to D_4. The switches are employed with IGBTs.

VI. Simulation Results

The simulation of the IPMSM electrical drive threelevel diode clamped IGBT inverter system is investigated. The control scheme applied for the electrical drive is the field oriented control (F.O.C).

Three modulation techniques have been applied to the three level voltage source inverter. The system used was investigated for steady and transient state. The output waveforms of SPWM, SVPWM and CBSVPWM are shown below. The parameters used in this simulation are shown in below:

L_d =0.0066; L_q=0.0058; R=1.4; PM_flux=0.1546;

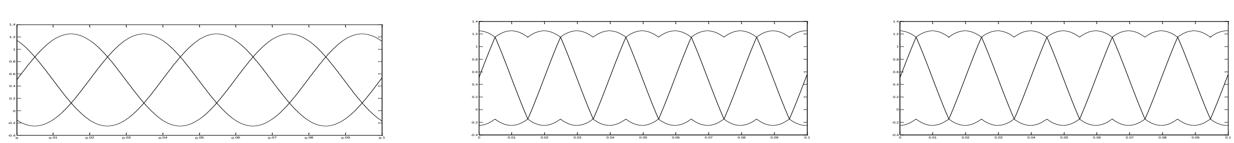
P=6; F=0.000038818; J=0.00176

VII. Conclusion

In this paper, the simulation model of closed loop control of three-level diode clamped inverter fed IPMSM drive using three different modulation techniques has studied. The output voltage, current of the inverter and the speed, torque and the three-phase currents of the IPMSM for SPWM, SVPWM and CBSVPWM have plotted. From the analysis we can conclude that the CBSVPWM is similar to SVPWM but much simple, easy and the fastest method without much mathematical calculations like angle and sector determination as in SVPWM. This method can be easily extended to n-level inverter. THD of voltage and current also reduces with CBSVPWM.

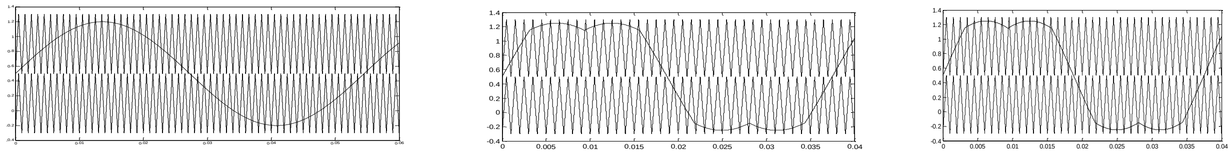
Table 2 : Comparison of THD for voltages and currents using SPWM, SVPWM, CBSVPWM

THD	SPWM	SVPWM	CBSVPWM
Line voltage	41.09	39.65	26.27
Line current	7.07	4.99	3.11



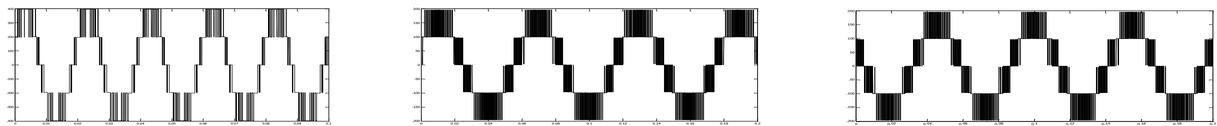
(a) (b) (c)

Figure 8 : Reference waveforms of SPWM(a),SVPWM(b), CBSVPWM(c)



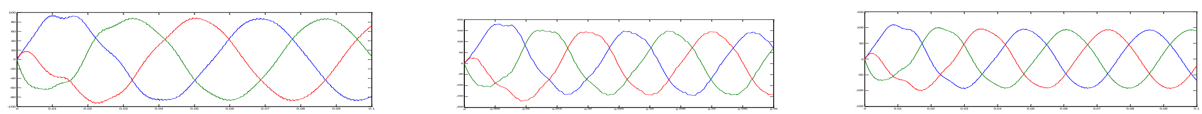
(a) (b) (c)

Figure 9 : Ref _carrier waveform of SPWM(a),SVPWM(b) and CBSVPWM(c)



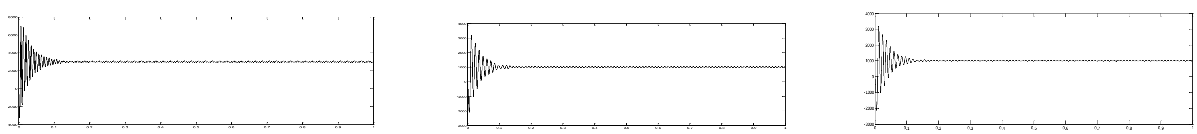
(a) (b) (c)

Figure 10 : Output voltage waveform of Three-level diode clamped inverter using SPWM(a), SVPWM(b) & CBSVPWM(c)



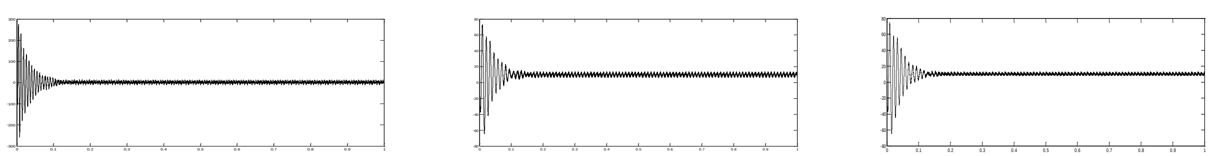
(a) (b) (c)

Figure 11 : Output three phase current waveform of Three-level diode clamped inverter using SPWM(a), SVPWM (b) and CBSVPWM(c)



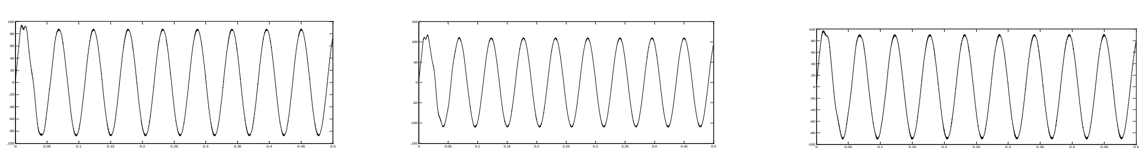
(a) (b) (c)

Figure 12 : Output speed response of Three-level diode clamped inverter fed IPMSM using SPWM(a), SVPWM (b) and CBSVPWM(c)



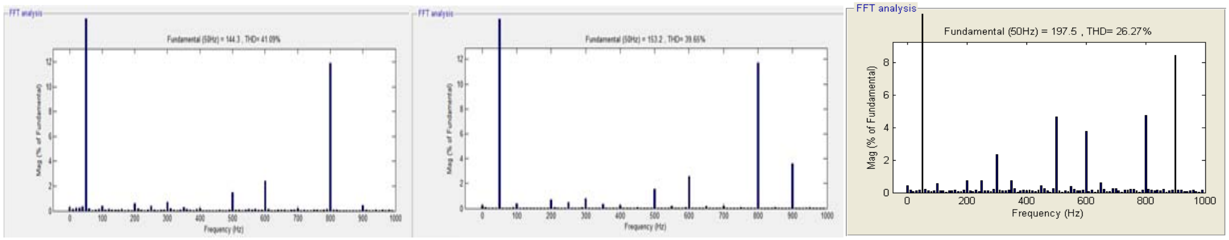
(a) (b) (c)

Figure 13 : Output torque response of Three-level diode clamped inverter fed IPMSM using SPWM(a), SVPWM (b) and CBSVPWM(c)



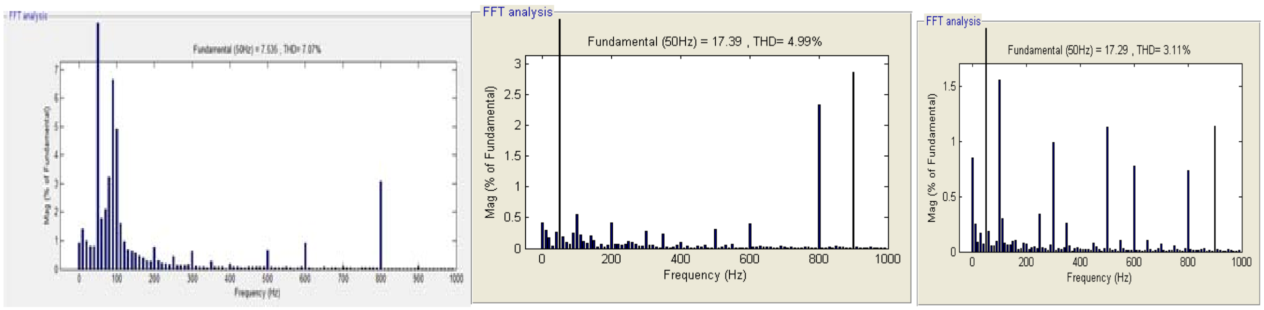
(a) (b) (c)

Figure 14 : Output phase current waveform of Three-level diode clamped inverter fed IPMSM using SPWM (a), SVPWM (b) and CBSVPWM(c)



(a) (b) (c)

Figure 15 : THD of output line voltage of three-level diode clamped inverter fed IPMSM using SPWM(a), SVPWM (b) and CBSVPWM(c)



(a) (b) (c)

Figure 16 : THD of output phase current of Three-level diode clamped inverter fed IPMSM using SPWM(a), SVPWM(b) and CBSVPWM(c)

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Performance Analysis of EDFA for Different Pumping Configurations at High Data Rate

By Ms. Prachi Shukla & Asst. Prof. Kanwar Preet Kaur
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GJRE-F Classification : FOR Code: 090607, 290901

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Strictly as per the compliance and regulations of :

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Ms. Prachi Shukla [α] & Asst. Prof. Kanwar Preet Kaur [σ]

Abstract - The performance of Erbium Doped Fiber Amplifier (EDFA) depends on various parameters like, Er^{+3} doping concentration, active fiber length, pump power, pumping wavelength etc. In this paper, the analysis of gain and noise figure (NF) of EDFA is done at different pump power (10, 50, & 100mw) and at different fiber length (10, 30, & 50m) for different pumping configuration i.e. forward pumping, backward pumping, and bidirectional pumping operating in C-band at high data rate.

Keywords : erbium doped fiber amplifier (EDFA), erbium doped fiber (EDF), gain, noise figure (NF).

I. Introduction

In long-haul point-to-point optical fiber communication the signal traveling inside the fiber suffers from various losses like fiber attenuation losses, fiber tap losses, fiber splice losses, etc., due to these losses it is difficult to detect the original signal at the receiver side. So in order to transmit signal over a long distance in a fiber it is necessary to compensate all losses in the fiber. The introduction of optical amplifiers allowed the signal amplification in optical domain. There was no need to convert the optical signal to electrical signal. There are mainly two types of optical amplifiers: semiconductor optical amplifier and fiber amplifiers. Fiber amplifiers are classified as erbium doped fiber amplifier (EDFA), Raman amplifier and Brillouin amplifier.

EDFA is made by a popular material for long–haul telecommunication applications that is a silica fiber doped with erbium (Er^{+3}) ions [1, 2]. Er^{+3} ions are having the optical fluorescent properties that are suitable for the optical amplification. The advent of EDFA has enable the optical signals in an optical fiber to be amplified directly in high bit rate systems beyond Terabits. One of the most important factors limiting the transmission distance in fiber optical communication systems is the optical power loss caused by scattering and absorption mechanisms in optical fiber [4, 7].

EDFA is suitable to operate at the conventional (C) band from about 1530 to 1565 nm. Since the entire C band of EDFA is fully utilized, the need for more optical channels and wider optical bandwidth urges EDFA technology to develop beyond its present limits. To extend the optical bandwidth and increase the number of WDM channels, L-band optical amplifiers are used to operate in longer wavelength from about 1570 to 1605 nm. EDFA by itself has a very low-gain at the L-band, most realizations of L-band EDFA implement a long length of erbium-doped fiber (EDF) to pump up its gain. A typical L-band EDFA also has larger noise figure than C-band EDFA. Unlike EDFA have the problems of un pumped amplifier attenuations and the operation wavelength constrained at 1.53-1.56 μm region, Raman fiber amplifier (RFA) has merit of arbitrary gain bandwidth, which were recently being recognized as an enabling technology for high capacity and long-haul density wavelength-division-multiplexing (DWDM) systems. RFA can be used to amplify not only the C-band, but also the S-, L- and other bands, depending on the usage of the pumped wavelengths. RFA has several advantages including lower noise figure (NF), flexibility on the selection of gain medium, and wide gain bandwidth, especially that RFA has the capability to "distribute" the gain over a long distance in the transmission fiber. Thus, L-band optical amplifier is better to adopt RFA rather than L band EDFA [11]. As EDFA can operate in a broad range within the 1550 nm [9, 10] window at which the attenuation of silica fiber is minimum and therefore it is ideal for the optical fiber communication systems operating at this wavelength range. Hence it is very useful in WDM for amplification. According to the research performed in recent years, it is known that the pumping of EDF at 980 nm or 1480 nm is the most efficient way. High gain (30∼50dB), large bandwidth (>90 nm), high output power (10∼20 dBm) and low NF (3∼5 dB) can be obtained using an EDFA optimized for 1550 nm range [3, 5].

II. EDFA Architecture

An optical fiber consists of a doped fiber, one or more pump lasers, a passive wavelength coupler, optical isolators, and tap couplers. The wavelength selective coupler couples both the pump and signal optical power efficiently into the fiber amplifier. The tap couplers are wavelength insensitive and are generally used on both sides of the amplifier to compare the incoming signal with the amplifier output. The optical isolators prevent the amplified signal from reflecting back into the device, where it could increase the amplifier noise and decrease its efficiency [2]. Typically, the EDFA configuration can be categorized by pumping

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schemes into three particular arrangements. These schemes are Forward-pumped (co-pumped), Backward-pumped (counter-pumped), and Bidirectional-pumped (Dual-pumped) [6]. Pumping at a suitable wavelength provides gain through population inversion the gain spectrum depends on the pumping scheme as well as on the presence of other dopants, such as germanium and alumina, within the fiber core [1, 6].

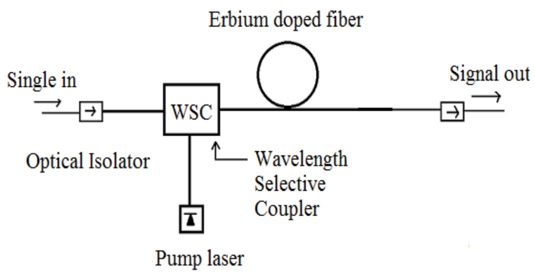

Figure 1 : Forward pumped EDFA structure

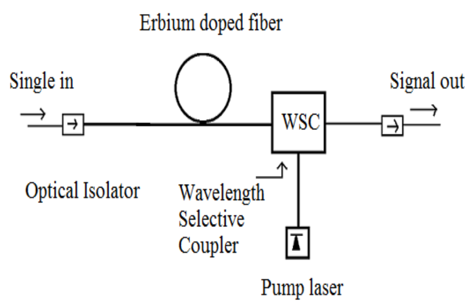

Figure 2 : Backward pumped EDFA structure

In forward pumping, figure 1, the input signal and the pump signal propagate in the same direction inside the fiber [2]. The input signal and pump are combined using a pump combiner or wavelength selective coupler. Inside the fiber the pump energy is transferred to the input signal and the signal is amplified at the output of the amplifier. Isolators are used in the scheme to make sure that the signal will travel only in one direction and no feedback of signal will occur.

In backward pumping, figure 2, the input signal and the pump signal propagate in the opposite direction to each other inside the fiber.

In Bi-directional pumping, figure 3, the input signal travels in one direction. But the there are two pump signals that travel inside the fiber. One pump signal travels in the same direction as the input signal and the other pump signal travels in the opposite direction to that of the input signal.

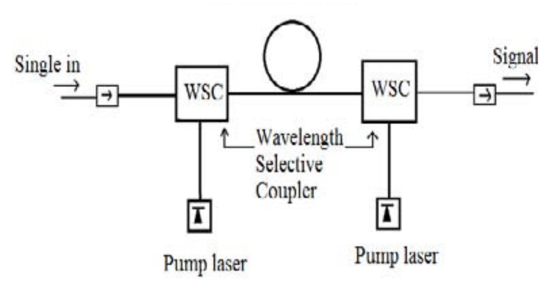

Figure 3 : Bidirectional pumped EDFA structure

III. Simulation Setup

An EDFA model based on work by Giles is used to find the amplifier performance at a high bit rate. The simulation set up consist of the continuous wave laser, 100mW peak power of pump laser, operates in single mode and no laser random phase. The optical multiplexer is used to combine the signals obtained from the output of pump laser and CW Laser. EDF has 1552.5 nm wavelength, length 50m (maximum), metastable lifetime of 10ms. The bit-time in simulation, i.e. the time-duration of the bit, must be an integer number of time-samples NS (samples per bit value). Parameters of basic attribute section taken are 10 and 40 Gb/s bit rate and 64 samples per bit. The measurement components used are optical spectrum analyzer and dual port WDM analyzer.

Table I : Typical EDFA Parameters used in the Simulation Program

Model Parameter	Value
Pump absorption cross section	1.8×10^{-25} m^2
Signal absorption cross section	2.14×10^{-25} m^2
Pump emission cross section	3.15×10^{-25} m^2
Signal emission cross section	3.80×10^{-25} m^2
Fiber radius	2 µm
Length of EDF	10,30, & 50m
Pumping power	10,50,& 100mw
Signal input power	10 dBm
Signal wavelength	1552.5 nm
Pump wavelength	980nm
Er^{+3} ion density	1e+025 m^{-3}

This paper focuses on the performance characteristics of the amplifier (gain and NF) assuming the fundamental LP_{01} mode exciting at the pump wavelength ($\lambda p=$ 980 nm) [6]. The gain and NF can be obtained for all the three pumping configurations as a function of two fundamental fiber parameters namely: fiber length, and pump power. Thus, the required fiber parameters and pump power values can be optimized for a desired EDFA gain-NF performance at 10 and 40 Gbps. The main parameters of the simulation are shown in Table I.

IV. Results & Discussion

In this paper the variation of Gain and NF for EDFA is analyzed with different pumping techniques i.e. forward pumping, backward pumping and bidirectional pumping. And also the variation of gain and NF is analyzed for different EDF length (10, 30, & 50 m) and at different pumping power (10, 50 & 100 mW). The length of the EDF depends upon the input signal power, pump power, Er^{+3} ion density and the signal and pump wavelength.

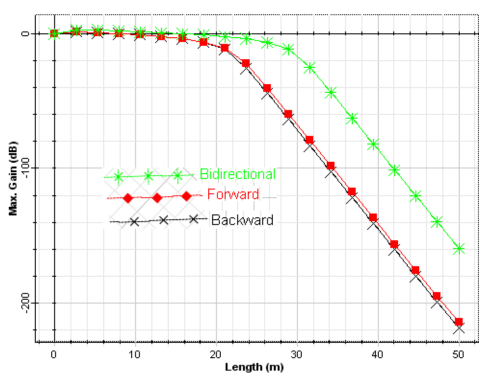

Figure 4 : Gain vs. fiber length at 10mW pump power

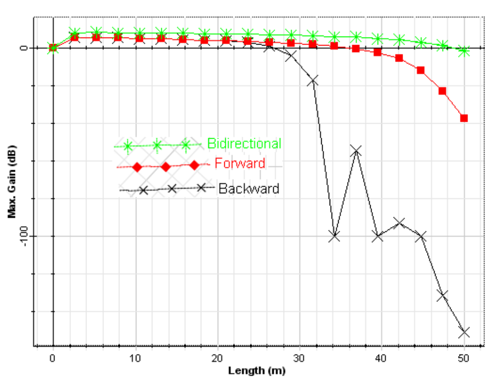

Figure 5 : Gain vs. fiber length at 50mW pump power

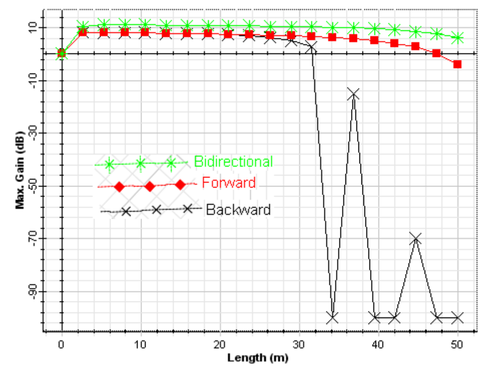

Figure 6 : Gain vs. fiber length at 100mW pump power

Almost same results are obtained for high data rates of 10 Gbps and 40 Gbps. This means that change in data rate does not affect the gain and NF of the three pumping configurations for single channel signal transmission.

a) Gain Characteristics

The gain of different pumping configuration is varied along with the fiber length is shown in figures 4, 5, and 6 at different pump powers 10, 50, and 100 mW, respectively, having a constant signal input power, Er^{+3} ion density, signal wavelength, and pump wavelength. Form the figures it is seen that the maximum gain flatness is obtained for a wider range of fiber length in case of bidirectional pumping configuration at a higher pump power of 100 mW. On comparing the graphs it can be concluded that in case of bidirectional pumping configuration as the fiber length is increased the pump power should be increased to obtain higher value of gain and its flatness for higher range of fiber length. Whereas backward pumping gives the worst results but forward pumping shows acceptable results but values are less than bidirectional pumping configuration. If the Er^{+3} ion density is decreased to 1e+024 m^{-3} forward and backward pumping configurations gives flat gain for fiber length range which is less as compared to the Er^{+3} density of 1e+025 m^{-3} for bidirectional pumping configuration.

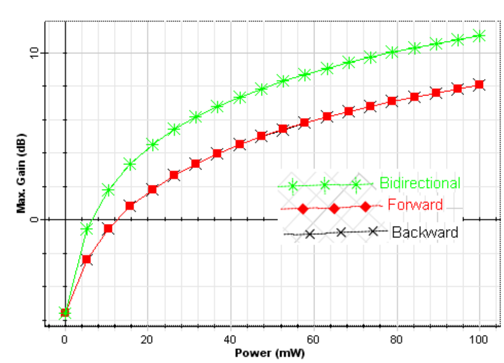

Figure 7 : Gain vs. pump power at 10m fiber length

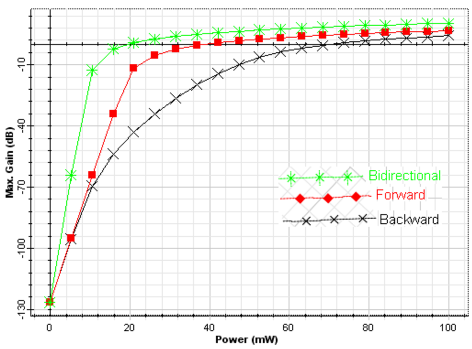

Figure 8 : Gain vs. pump power at 30m fiber length

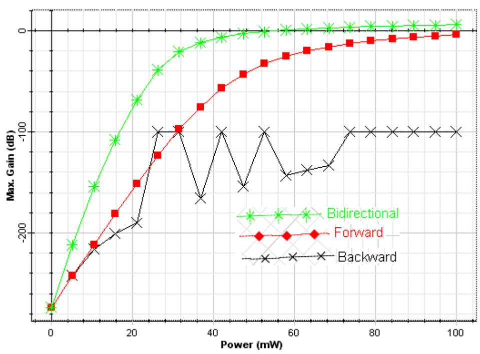

Figure 9 : Gain vs. pump power at 50m fiber length

Now gain of different pumping configuration is varied along with pump power for different fiber lengths 10, 30, and 50m at constant parameters mentioned above and is shown in figures 7, 8, and 9, respectively. Comparing figure 7, 8, and 9 it is seen that in the case of bidirectional pumping configuration gain is much flat for wider range of pump power at the fiber length of 30m as compare to forward and backward pumping configuration. But as length further increases gain value decreases. To maintain consistent results Er^{+3} ions density should be kept at 1e+025 m^{-3} and is obtained for bidirectional pumping configuration.

b) Noise Figure Characteristics

The NF of different pumping configuration is varied along with the fiber length at different pump power 10, 50, and 100 mW as shown in figure 10, 11, and 12, respectively, and the variation of NF with the pump power at different fiber length of 10, 30, and 50m is shown in figure 13, 14, and 15, respectively, having a constant signal input power, Er^{+3} ions density, signal wavelength, and pump wavelength.

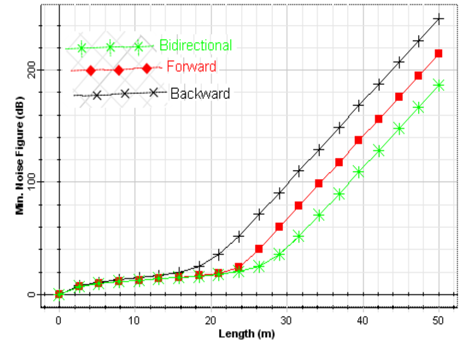

Figure 10 : Noise figure vs. fiber length at 10mW pump power

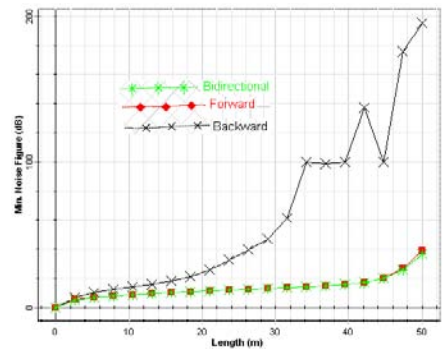

Figure 11 : Noise figure vs. fiber length at 50mW pump power

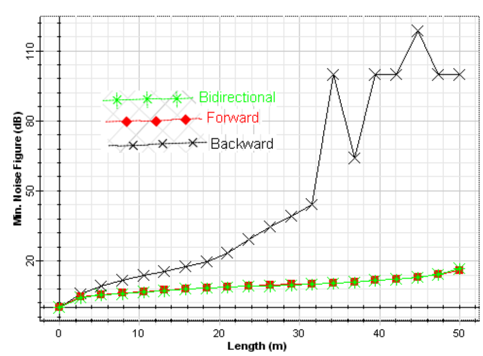

Figure 12 : Noise figure vs. fiber length at 100mW pump power

From the figures 10, 11, and 12 the bidirectional and forward pumping configuration gives miminum NF at the pump power of 100mW as compare to backward pumping configuration. Also from the figures 13, 14, and 15 in the case of bidirectional and forward pumping configuration the minimum NF is obtained at the fiber length of 30m for a wide range of pump power. But as the fiber length increases pump power should also be increased to minimize NF. Thus when the pump power increases the minimum NF is achieved at the fiber length of 30m for forward and bidirectional pumping configuration. But the Er^{+3} ion density is kept at 1e+024 m^{-3} then as the fiber length increases the NF increases even if the pump power is increased. Hence the Er^{+3} ion density is set as 1e+025 m^{-3}.

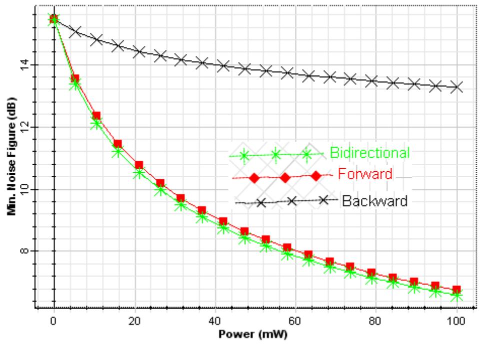

Figure 13 : Noise figure vs. pump power at 10m fiber length

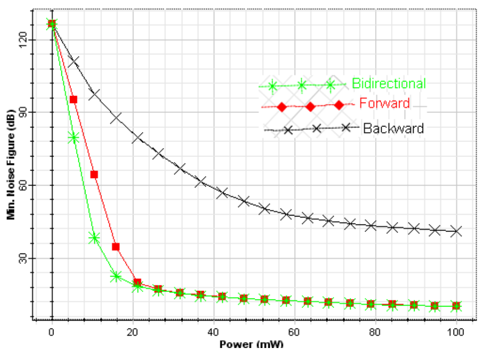

Figure 14 : Noise figure vs. pump power at 30m fiber length

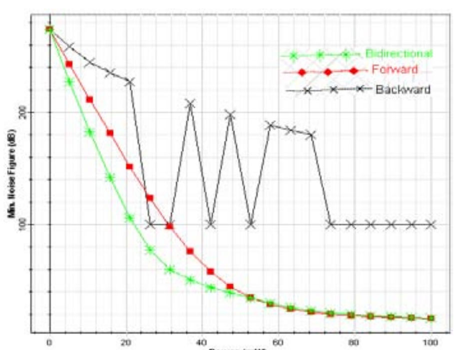

Figure 15 : Noise figure vs. pump power at 50m fiber length

V. Conclusion

This paper gives the comparison of the three pumping configurations, i.e., forward, backward, and bidirectional pumping based on gain and NF at different pump power (10, 50, & 100mw) and at different fiber length (10, 30, & 50m) operating in C-band, 10dBm signal input power, 980nm pump wavelength, and Er^{+3} ion density of 1e+025 m^{-3}. It is found that the minimum NF occurs for both forward and bidirectional pumping configuration whereas flat gain is obtained by using bidirectional pumping configuration. Thus bidirectional pumping configuration can be said to be the best configuration. It is also seen that when the fiber length increases the pump power should be increased in order to achieve the flat gain and minimum NF by maintaining the Er^{+3} ions density at higher value. Also any increase in data rate doesn't cause any change in the results of all the configurations. This paper shows that although the flat gain is achieved but efforts must be done to increase the value of gain.

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Implementation of a Low Cost 5 Level PWM Inverter

By Neelashetty Kashappa & Ramesh Reddy K
University's Visvesvaraya College of Engineering (UVCE), India

Abstract - This paper deals with the implementation of a new low cost five level inverter which converts the 9V DC to 9V AC. Complexity and cost of the system are reduced as compared to other configurations by using only five switches, eight diodes and two capacitors. In the proposed scheme, control circuit is designed using 89C51 microcontroller to produce sinusoidal pulse width modulation(SPWM).The developed system can be operated at very high modulation frequencies of upto 200 KHz producing sustained output. This single-phase five level low cost inverter is developed and tested in power electronics laboratory. The waveforms are recorded and analyzed using Digital Storage Oscilloscope TDS2024B. The proposed scheme is very economic and less complex and the experimental results shows that it has low total harmonic distortion.

Keywords : *low cost, pulse width modulation, multilevel inverter, total harmonic distortion.*

GJRE-F Classification : *FOR Code: 290903*

IMPLEMENTATION OF A LOW COST 5 LEVEL PWM INVERTER

Strictly as per the compliance and regulations of :

Implementation of a Low Cost 5 Level PWM Inverter

Neelashetty Kashappa [α] & Ramesh Reddy K [σ]

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Indexterms : low cost, pulse width modulation, multilevel inverter, total harmonic distortion.

I. Introduction

The field of power electronics has witnessed tremens-dous development in recent years. The advent of new power controlled devices has contributed significantly to an enhanced performance of the existing power converters. The birth of innovative converter/inverter topologies has paved the way for further improvement in the overall power quality. Multilevel inverter has gained much attention and became more popular now a day due its high quality output waveforms, low switching losses and high voltage capability, less EMI and reduced harmonics [1]. Using multilevel inverters specific harmonics can be eliminated in order to generate less distorted sinusoidal waveform. The main features of multilevel inverters are summarized as (i) The staircase waveform of a multilevel inverter not only removes certain specific harmonics, but it also reduces the dv/dt stress. (ii) Smaller common mode (CM) voltage of multilevel inverter helps to reduce the stress in the bearing of a motor connected to multilevel inverter drive. (iii) Multilevel inverter has a capability to operate both at high switching frequency and fundamental switching frequency [1-2]. The multilevel inverters can be used medium voltage to high voltage range applications. It covers wide range areas including Uninterruptible Power Supplies (UPS), DC power source utilization, induction heating, high power motor drives, HVDC power transmission, electric vehicle drives, power distribution etc. Multilevel inverters works as voltage synthesizers. That is many smaller voltage levels synthesize high output power. The main drawback of multilevel inverter is that, as the number of levels are increased, the amount of diodes, switching devices and other required components increases causing the inverter more complex and costly[3].

A survey of topologies, control and applications of multilevel inverters is given by Rodriguez and Peng (2002). The way to balance Dc link voltages of diode clamped multilevel converters is given by Marchesoni and Tensa (2002). UPFC based chopper stabilized diode clamped multilevel converters is given by Chen Mwinyiwiwa (2000). Pulse width modulation for diode clamped multilevel converters is given by venkatra-manand (2002). Fundamental characteristics of Five-level converter for induction motor drives is given by Ishida and Sasagawa (2002). Control strategies for multilevel voltage source converters is given by J Von (2000). Diode clamped multilevel inverter for statcom is given by Chengand (2002). Simulation optimization system for multilevel inverters is given by tourkhani and Meynard (1999). Performance of medium voltage multilevel inverter is given by Hilland Harbourt (1999). Comparison of 3-level and 9-level inverter-fed induction motor drives is given by Neelashetty K and Ramesh Reddy K (2010). Performance of voltage source multilevel inverter-fed induction motor drive is given by Neelashetty K and Ramesh Reddy K (2011). Investi-gations on 7-level and 9-level inverter-fed induction motor drives is given by Neelashetty K and Ramesh Reddy K (2011). Literature survey does not deal with cost, complexity as well as the Total Harmonic Distortion (THD) of a multi level inverter. Therefore this work is taken up and it deals with the implementation of a low cost pulse width modulation voltage source five level inverter.

II. Implementation of Five Level Inverter

a) Total harmonic distortion

The Total Harmonic Distortion (THD) is a measure of amount of harmonic distortion present. It is defined as the ratio of sum of the power of all harmonic components to the power of fundamental frequency. In other words total harmonic distortion is the measurement of extent of that distortion.

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Total harmonic distortion for the power signal can be expressed as follows:

$$\text{THD} = \frac{\sum P_2 + P_3 + P_4 + \ldots + P_n}{P_1} \quad (1)$$

Total harmonic distortion for the voltage signal can be expressed as follows:

$$\text{THD} = \frac{\sum V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2}{V_1^2} \quad (2)$$

Where, V_n means RMS voltage of n^{th} harmonic, V_1 is the voltage at the fundamental frequency.

The simplified approach for the THD is given by

$$\text{THD} = \frac{V_{RMS}^2 - V_1^2}{V_1^2} \quad (3)$$

Many times amplitude ratio is taken into consideration for the measurement of total harmonic distortion and is given by

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2}}{V_1^2} \quad (4)$$

This latter definition is the one commonly used in audio distortion specification.

Choosing appropriate conducting angles for the H-bridges can eliminate a specific harmonic in the output waveform (Rashid, 2004). The required conduction angles can be calculated by analyzing the output phase voltage of cascaded inverter assuming that four H-bridges have been used. The output voltage V_{ao} can be given as

$$V_{ao} = V_{a1} + V_{a2} + v_{a3} + V_{a4} + V_{a5} \quad (5)$$

Since the wave is symmetrical along the x-axis, both Fourier coefficients A_0 and A_n are zero. Just the analysis of B_n is required. It is given as; analysis of B_n is required. It is given as;

$$B_n = \{[4V_{dc}]/n\pi\} \left[\sum_{j=1}^{\infty} \text{Cos}\,(n\alpha_1) \right] \quad (6)$$

j=Number of DC sources.

n=Odd harmonic order.

Therefore, to choose the conducting angle of each H-bridge precisely, it is necessary to select the harmonics with certain amplitude and order, which needs to be eliminated. To eliminate 5th, 7th, and 11th harmonics and to provide the peak fundamental of the phase voltage equal to 80 percent of its maximum value, it needs to solve the following equation with modulation index M=0.8

$$\text{Cos } 5\alpha_1 + \text{Cos } 5\alpha_2 + \text{Cos } 5\alpha_3 + \text{Cos } 5\alpha_4 = 0$$

$$\text{Cos } 7\alpha_1 + \text{Cos } 7\alpha_2 + \text{Cos} 7\alpha_3 + \text{Cos} 7\alpha_4 = 0$$

$$\text{Cos} 11\alpha_1 + \text{Cos} 11\alpha_2 + \text{Cos} 11\alpha_3 + \text{Cos} 11\alpha_4 = 0$$

$$\text{Cos}\alpha_1 + \text{Cos}\alpha_2 + \text{Cos}\alpha_3 + \text{Cos}\alpha_4 = 0.8*4$$

In this case, one of the very efficiently used control strategies is the space vector based control, which can be implemented using digital signal processor.

b) System Overview

The block representation of multilevel inverter is shown in figure1. It consists of a 9V battery, five level H-bride inverter, step-down transformer, control circuit and load. The elementary components of singe-phase multilevel inverter are MOSFETs, diodes and capacitors. A 9V DC source is given to the H-bridge multilevel inverter through two capacitors. These two capacitors functions as voltage dividers. The control circuit mainly consists of 89C51 microcontroller and optoisolator. The control circuit not only controls the system, but can also generate the pulse width modulation (PWM) signals. The most efficient method of controlling the output voltage is to incorporate the PWM signals within the inverter. These PWM signals are given to the gate of each MOSFET through the gate drive circuit. The switching of the MOSFETs is controlled by the PWM signals. This switching results the ac output voltage. This output voltage is synthesized by different small voltage levels to get a very high quality staircase output waveform. This waveform has reduced harmonic and switching losses. This high quality output voltage can be used to drive the load. The inverter has the ability to drive both resistive as well as inductive loads. Hence the proposed scheme can be used to control the induction motor. The main advantage of this proposed scheme is that, it can also be used for three phase applications. As all electronic circuits works with low DC voltage a power supply unit is required to provide the appropriate voltage supply for their proper functioning. This power supply unit consists of transformer, rectifier, filter and regulator. AC voltage of typically 230V RMS is connected to a transformer which steps down the voltage to the desired AC voltage. The diode rectifier provides the full wave rectified voltage that is initially filtered by a simple capacitor filter to produce a DC voltage. This resulting DC voltage usually has some ripple or AC voltage variation. A regulator circuit can use this DC input to provide DC voltage that not only has much less ripple voltage but also remains at the same DC value, even when the input DC voltage varies somewhat or the load connected to the output DC voltage changes.

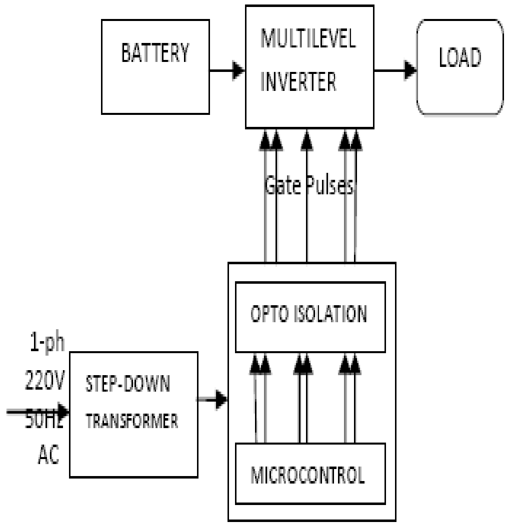

Figure 1 : Block diagram of complete proposed system

III. Power and Control Circuit Design

The power circuit is designed using MOSFETs, capacitors and diodes. Single-phase H-bride topology is used in this work. The biggest advantage of this proposed scheme is that, the components used in the design are very less compared to other topologies. This topology achieves nearly 40% reduction in the components. This reduces the complexity and cost of the system. Hence it can be efficiently used for the medium power applications. The control circuit is designed using ATMEL 89C51 microcontroller. The microcontroller is programmed using C language. A Keil C is used as integrated development environment for developing the required embedded system. The control circuit is mainly responsible for generating the pulse width modulation (PWM) signals given to gate of each MOSFET through separate optoisolator and gate drive circuit. These PWM signals controls the turning on and off of the MOSFETs. A dead time of 2 microseconds is given between turning on and off of MOSFETs and vice versa. In this proposed scheme a duty cycle of 50% is used.

IV. Experimental Results

A new low cost H-bridge multilevel inverter is developed and tested in power electronics laboratory. The various waveforms are analyzed and recorded using digital storage oscilloscope. The experimental waveforms for the output current of the 3-level is shown in fig 2a and the corresponding FFT spectrum is shown in fig 2b. The experimental waveforms for the output current of the 5-level is shown in fig 3a and the corresponding FFT spectrum is shown in fig 3b. From the spectrum it can be seen that the THD in 3-level inverter is 7.46 percent and the THD in the 5-level inverter is 7.09 percent. Thus the THD is reduced by 5 percent. The output waveform of 5-level inverter is staircase in its nature and has

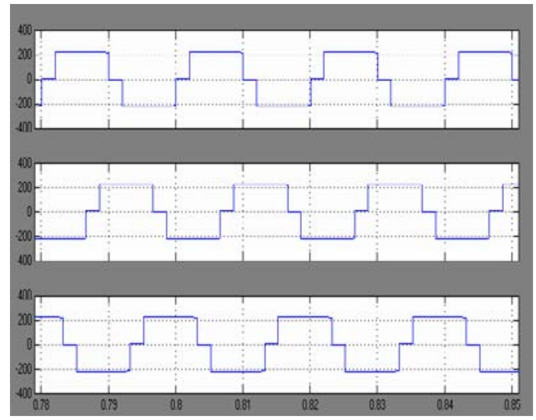

Figure 2 a : Experimental waveform of 3-level inverter output

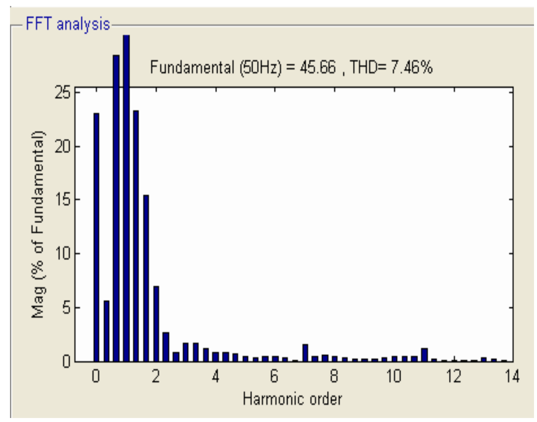

Figure 2 b : FFT analysis for 3-level inverter output

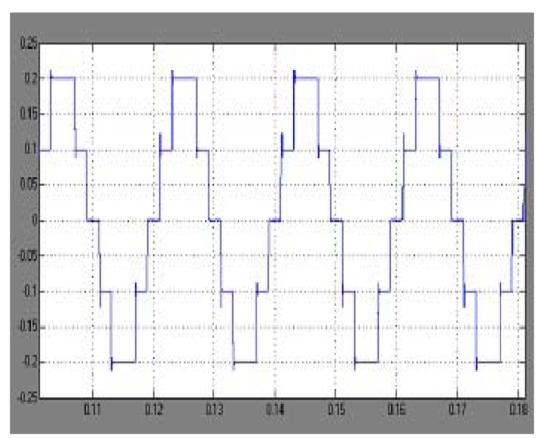

Figure 3 a : Experimental waveforms of 5-level inverter output

very high quality. The proposed H-bridge five level inverter converts 9V DC to 9V AC With reduced cost, less complexity and low THD compared to a 3-level inverter. The photograph of the top view of the hardwired system is shown in fig 4.

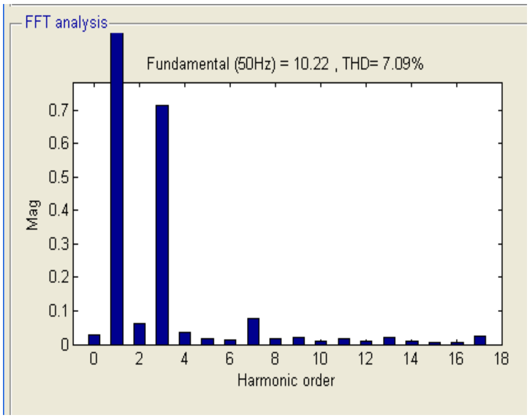

Figure 3 b : FFT analysis for 5-level inverter output

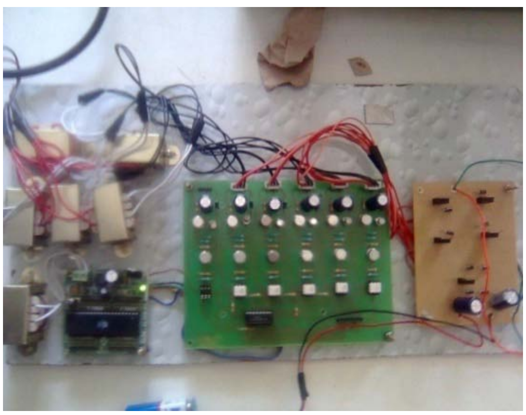

Figure 4 : The photograph of hardwired system

V. Conclusion

A laboratory prototype of H-bridge five level inverter is developed. The proposed topology has successfully converted 9V DC to 9V AC with reduced cost, less complexity and low THD. The experimental results of 5-level inverter system are compared with the 3-level inverter system. It is observed that the total harmonic distortion produced by 5-level inverter system is less than that of a 3-level voltage source inverter system. The THD is reduced by 5 percent. Therefore the heating due to 5-level inverter system is less than the 3-level inverter system. The proposed system is economic, efficient and reliable and can be used for medium as well as high power applications. The experimental waveforms and the FFT spectrums are presented. The hardware module is implemented using embedded controller.

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Three-Phase Induction Motor's Torque under Voltage Unbalance

By Sobhan Ghanbari, Pezhvak Sheikhzadeh-Baboli & Rouhollah Falahati-Naghib
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Abstract - Considering widely use of three-phase induction motors in industry, commercial and residential applications and the probability that they may exposed to the unbalanced voltages, it is very important to clarify the effects of voltage unbalance on the performance of them.

In this paper, authors simulated a three phase squirrel cage induction motor under six types of unbalanced voltages with same VUF combined with under voltage or over voltage in one or more phases using two-dimensional finite element method. Electromagnetic torque of the mentioned motor analyzed and effects of voltage unbalance on its average torque and torque ripple investigated and also, emphasized to detect unbalance condition, torque frequency analysis can be used.

Keywords : finite element method, induction motor, torque analysis, unbalanced voltages, VUF, ripples.

GJRE-F Classification : FOR Code: 090699

THREE-PHASE INDUCTION MOTORS TORQUE UNDER VOLTAGE UNBALANCE

Strictly as per the compliance and regulations of :

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Sobhan Ghanbari [α] , Pezhvak Sheikhzadeh-Baboli [σ] & Rouhollah Falahati-Naghib [ρ]

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I. Introduction

Voltage unbalance combined with under- or over voltage is a voltage quality problem. The mentioned phenomenon can be found in a three-phase power system commonly. Different factors cause unbalanced voltage in power system including unbalanced loads, incomplete transposition of trans-mission lines, open-Y, open-Δ transformer connections, blown fuses on three-phase capacitor banks and etc. The induction motors are widely used in industrial, commercial and residential applications and most of them are connected directly to electric power distribution system (PDS). Therefore it is very important to clarify the effect of voltage unbalance on the performance of IM (Hirotsuka et al., 2006).

The unbalanced voltages induces negative sequence current and mentioned current produces a backward rotating field in addition to the forward rotating field produced by the positive sequence one. The interaction of these fields produces pulsating electromagnetic torque and ripple in velocity (Alwash and Ikhwan, 1995; Smith and Dorrell, 1996) Such condition has severe impacts on the performance of an induction motor.

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The in fluence of unbalance on the efficiency (Lee, 1999), increase of losses, and the negative effects on the insulation life (Gnaci´nski, 2008), temperature rise, and life reduction (Pillay and Manyage, 2006), derating in the machine (Anwari and Hiendro, 2010) are some contributions in this area.

II. Different Definitions of Voltage Unbalance in Standards

There are three general definitions for measuring the voltage unbalance in standards. The first definition is *LVUR*, given by NEMA, is as follow (NEMA MG 1, 2003):

$$LVUR = \frac{\max\left[\left|V_{ab}-V_{avg}\right|,\left|V_{bc}-V_{avg}\right|,\left|V_{ca}-V_{avg}\right|\right]}{V_{avg}}\times 100 \qquad (1)$$

In (1) V_{ab} , V_{bc} and V_{ca} are line-to-line voltages.

$$V_{avg} = \frac{V_{ab}+V_{bc}+V_{ca}}{3} \qquad (2)$$

The second definition for voltage unbalance has been given by the IEEE Std 141 is PVUR as follow:

$$PVUR = \frac{\max\left[\left|V_{a}-V_{avg}\right|,\left|V_{b}-V_{avg}\right|,\left|V_{c}-V_{avg}\right|\right]}{V_{avg}}\times 100 \qquad (3)$$

Where

$$V_{avg} = \frac{V_{a}+V_{b}+V_{c}}{3}\times 100 \qquad (4)$$

In (3) V_a , V_b and V_c are phase voltages.

And The third definition is Voltage unbalance factor (*VUF)* has been given by IEC (Lee, 1999; Anwari and Hiendro, 2010):

$$VUF = \left|\frac{V_2}{V_1}\right|\times 100 \qquad (5)$$

Where, V_1 and V_2 represent the positive and negative sequence phase voltage components that they can be calculated with the application of the Fortescue transformation in the complex plane, as follow:

$$\begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (6)$$

Where $a = e^{j(2\pi/3)}$ is the Fortescue operator. The VUF then calculated as in (5).

III. Different Types of Voltage Unbalance

For this article, VUF selected to use. But this is significant they are many unbalanced voltages possible with the same voltage unbalance factor. In the present work following six different unbalanced cases are considered (Lee, 1999):

(1) Single phase over-voltage unbalance (1Φ-OV)
(2) Two phase over-voltage unbalance (2Φ-OV)
(3) Three phase over-voltage unbalance (3Φ-OV)
(4) Single phase under-voltage unbalance (1Φ-UV)
(5) Two phase under-voltage unbalance (2ΦUV)
(6) Three phase under-voltage unbalance (3ΦUV)

IV. Theoretical Aspects of the Electromagnetic Torque under Unbalanced Condition

A wide variety of research has been done on modeling of unbalanced condition in study of induction machines. In the unbalanced voltage operating condition the torque can be written as follow (Xu and Wang, 2007):

$$T = \frac{P}{\omega} = \frac{(P_0 + P_2)}{\omega} = T_0 + T_2 \tag{7}$$

Where, T_0 is the DC torque and T_2 is the torque component which frequency is twice the supply frequency. In a simpler way assuming induction motor as a RL load the torque can be written as:

$$T = \frac{\eta \times V \times I}{\omega} \tag{8}$$

In which *V* and *I* are input voltage and current of each phase respectively. Assuming sinusoidal waveforms for voltage and current this equation can be rewritten as follow:

$$T = K\cos(2\pi f + \alpha)\cos(2\pi f + \beta) \tag{9}$$

So,

$$T = K'\left[\cos(\alpha - \beta) + \cos(4\pi f + \alpha + \beta)\right] \tag{10}$$

Based on equation (10) the resulting torque would include a DC term and a term which frequency is twice the fundamental frequency of the applied voltage. In order to detect the unbalanced supply voltage this extra torque component can be used.

V. Using FEM

In this section authors introduced briefly about procedure of induction motor simulation using finite element method.

a) Analysis Model

Table I and Fig. 1 show the technical data of the analyzed motor and also, its meshed quarter cross section, respectively.

b) Time-Stepping 2D FEM

At the present study, time-stepping FEM is used for the analysis performance of mentioned induction machine. The dynamic equations of the induction machine can be written as follow (Krause, 1986):

$$V_i = RI_i + \frac{d\lambda_i}{dt} \tag{11}$$

In (11), *I* and *V* are current and voltages of the three phase stator windings, respectively. λ_i and R are the matrices of the phase flux linkage and stator winding resistances.

The dynamic equation of mechanical system of machine is (Krause, 1986):

$$T - T_{LOAD} = J\frac{d\omega}{dt} + B_m\omega \tag{12}$$

Table I : Technical data of three-phase induction motor

Item	Value	Item	Value
Input Voltage(V)	380	Stator outer diameter(mm)	150
Output Power(kW)	2.2	Rotor outer diameter(mm)	90
Frequency (Hz)	50	Core length(mm)	90
Rated current(A)	5.3	Air gap(mm)	0.3
Pole number	4	Stator lamination type	M530-50A
Rated speed(rpm)	1410	Rotor lamination type	M530-50A
Connection	Y	No. turns in stator coil	44

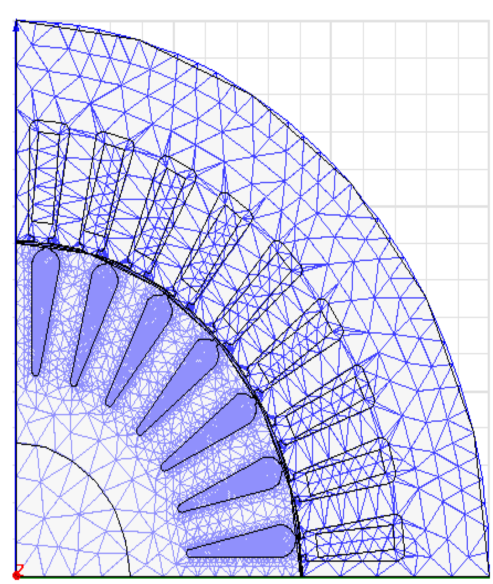

Figure 1 : Mesh description of the model

Where T, T_{LOAD}, ω, J and B_m are electromagnetic moving torque, load torque, velocity of the rotor, total moment of inertia of rotor and load, and damping, respectively.

In order to realize the variations of the load for simulated motor, a linear load torque with the following equation is considered as the load:

$$T_{LOAD} = \left(\frac{T_{FL}}{\omega_{rated}} \right) \times \omega_r \tag{13}$$

In (13), TFL is full load torque, ω_r , ω_{rated} are speed and rated speed, respectively.

The used voltages (and their positive and negative sequence components) in performance simulation of motor under unbalanced voltage condition are listed in Table II. These voltages are selected so that their VUF is similar and equal to 6%. Transient solver with step time equal to 0.1 ms is used in simulations. Quarter cross section of motor meshed with 9688 triangles. Simulation of each cycle (20ms) using 3GHz core 2do CPU and 2 Giga Byte of DDR2 Ram, consumed 236.3 seconds of time.

VI. Result and Discussion

a) Balanced Condition

Fig. 2 shows the electromagnetic torque of the simulated induction motor in time domain when supply voltage is balanced. This toque in frequency domain is showed in Fig. 3. The frequency analysis has been made using FFT. Ripple in torque waveform in time domain or in other words, torque components except DC component in frequency domain are mainly due to teeth slot effect. Skew is applied to electrical machines in order to reduce undesirable teeth slot effects such as cogging torques, higher-harmonic air-gap fields, torque ripple, vibrations, and noise (De Gersem et Al., 2003). But applied skew will be ignored in simulation using two dimensional finite element method therefore it can be expected that calculated ripple due to teeth slot effect is higher than corresponding value in the real skewed machine. However, ignoring the skew has not any significant error in study of the performance of electrical machines and 2D FEM is widely used in this area (Nemec et Al., 2010; Boglietti et Al., 2010; Dorrell et Al., 2009).

b) Unbalanced Condition

The electromagnetic torque of the motor under an unbalanced case (2Φ-OV) has been shown in Fig. 4. Fig.5 shows the mentioned torque in frequency domain. According to this figures, there is a 100 Hz component

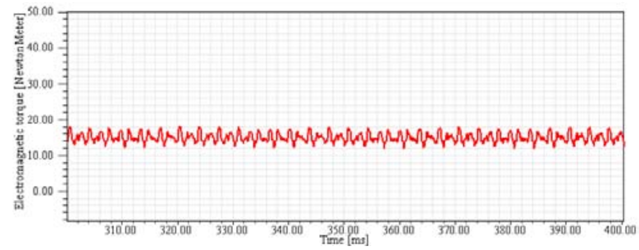

Figure 2 : Torque in balanced-voltage and time domain

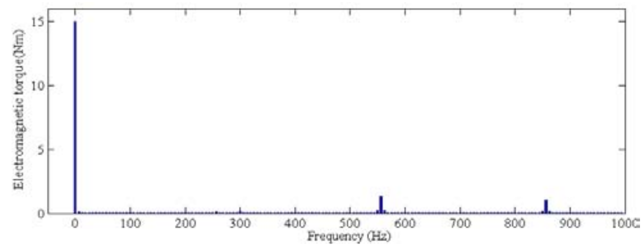

Figure 3 : Torque in balanced-voltage and frequency domain

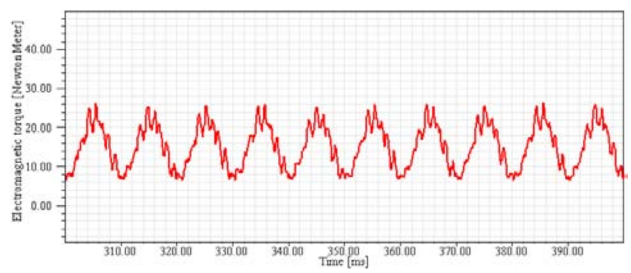

Figure 4 : Torque in unbalanced-voltage and time domain

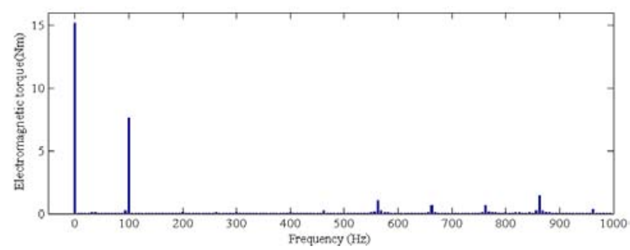

Figure 5 : Torque in unbalanced-voltage and frequency domain

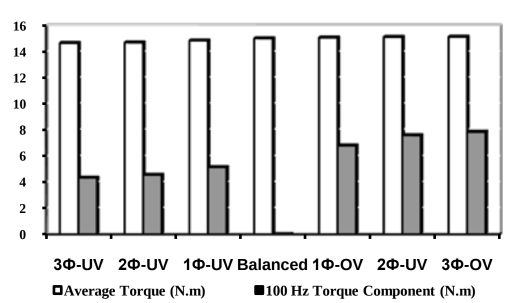

Figure 6 : Average and second component of electromagnetic torque for various condition of unbalanced voltage

Table II : The used voltage for unbalanced situation of three-phase induction motor

	3Φ-UV	2Φ-UV	1Φ-UV	1Φ-OV	2Φ-OV	3Φ-OV
V_a	178.27∠0	181.38∠0	182.07∠0	261.37∠0	270.35∠0	274.67∠0
V_b	185.18∠240	187.60∠240	219.39∠240	219.39∠240	249.96∠240	252.56∠240
V_c	215.93∠120	219.39∠120	219.39∠120	219.39∠120	219.39∠120	222.84∠120
V_1	193.1056	196.1426	206.9740	233.3962	246.5425	250.0010
V_2	11.5863	11.7694	12.4190	14.0031	14.7926	14.9999
PVUR	11.81	11.89	12.02	11.99	11	10.85
LVUR	6	6	5.91	6.1	5.44	5.35
VUF	6	6	6	6	6	6

with significant value in motor's torque as expected. Fig. 6 shows DC term and 2nd harmonic order of electromagnetic torque how change when induction motor supposed balanced and six various types of unbalanced voltages with same VUF equal to 6% as before mentioned. It can be seen in considered six types of unbalanced voltages, both average torque and 2nd harmonic order increase with increasing positive sequence voltage component. According to Fig.6, the unbalanced voltages does not always lead to reduced average torque of motor, even in case of unbalanced voltages combined with over voltage in one or more phases, average torque exceeded from equal value in balanced case. But this increase is not desirable because it would be associated with increased power losses and reduced efficiency (Lee, 1999). Note that when 2nd harmonic order of torque increases, ripple in velocity will increase. In other words, ripple in velocity increase with increasing positive sequence voltage component, also. The mentioned ripple in torque and velocity can be used to detect the unbalanced supply voltage for the induction motors that they may suppose unbalanced voltages.

VII. Conclusions

In this paper, performance of a three phase induction motor under six types of unbalanced voltages with same VUF has been simulated using 2D FEM and also, studied electromagnetic torque of the motor in this condition. It is seen that both average torque and torque ripple increase with increasing positive sequence voltage component for considered types of unbalanced voltages. Even in case of unbalanced voltages combined with over voltage in one or more phases, average torque exceeded from equal value in balanced case. Authors emphasized to detect unbalance condition, torque frequency analysis can be used.

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A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

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The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

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You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before
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Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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