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Chemical Stabilization of Expansive Clays from Algeria

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Abstracts -The occurrence of expansive clays causes serious stability problems in regions with arid climate. In these areas, the clay is so dry that a supply of a tiny quantity of water may release a fantastic energy capable of producing important damage in structure. This paper presents the chemical stabilization of three soils. In the first part, the potential swelling is estimated using indirect methods based on the geotechnical characteristics, thereafter, direct measurement of swelling parameters (magnitude and pressure of swelling) is carried out. The second part, deals with the study of the treatment of clays using several methods of stabilization (addition of NaCl salt, lime, cement, and association lime+ cement, and association lime + salt). The obtained rresults are very encouraging and show that for certain combinations the reduction rate in swelling potential is very important (about 90%).

Keywords : *arid region, expansive clay, swelling potential, stabilization, Algeria.*

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Chemical Stabilization of Expansive Clays from Algeria

M.K. Gueddouda[α], I. Goual[Ω], M. Lamara[β], A. Smaida[Ψ], B. Mekarta[¥]

Abstract - The occurrence of expansive clays causes serious stability problems in regions with arid climate. In these areas, the clay is so dry that a supply of a tiny quantity of water may release a fantastic energy capable of producing important damage in structure. This paper presents the chemical stabilization of three soils. In the first part, the potential swelling is estimated using indirect methods based on the geotechnical characteristics, thereafter, direct measurement of swelling parameters (magnitude and pressure of swelling) is carried out. The second part, deals with the study of the treatment of clays using several methods of stabilization (addition of NaCl salt, lime, cement, and association lime+ cement, and association lime + salt). The obtained rresults are very encouraging and show that for certain combinations the reduction rate in swelling potential is very important (about 90%).

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I. Introduction

Expansive soils are those which show volumetric changes in response to changes in their moisture content. Such soils swell when the moisture content is increased and shrink when the moisture content is decreased. Consequently, expansive soils cause distress and damage to structures founded on them. Algeria has witnessed tremendous development in its infrastructure over the last three decades. The problems of expansive soils seem to be overlooked during the design and construction of some of the projects especially in arid and semi-arid region (Lamara *et al.* 2005). As a result, some of these structures in Algeria were subjected to distress and damage and in worst cases some houses and roads were demolished.

The problems associated with expansive soils in Algeria are predominantly related to the presence of smectite clay minerals in tertiary rocks and quaternary soils. Expansive materials that exhibit swelling problems include bentonite mudstones, marls and silty mudstones, argillaceous limestones and altered conglomerates. The climate in Algeria is arid, with high evaporation rates, so that there is always a moisture deficiency in soils and rocks. Supply of water from any source is liable to cause ground heave in any soils or rocks possessing swelling potential. Damage caused by swelling soils for buildings and structures are considerable light (Tas 1992, Derriche et Kebaili 1998, Hachichi et Fleureau 1999, Djedid *et al.* 2002, Lamara *et al.* 2006).

However, in order to limit the disturbances in buildings, various solutions based on stabilization techniques have been developed with more or less satisfactory results. Stabilized soil is change some of these properties to improve its technical performance. Recently, Extensive studies have been carried out on the stabilization of expansive soils using various additives such different types of sand (quarry sand, dune sand and beach sand) and the dune sand combination + salt (NaCl) appeared to give encouraging results(lamara *et al.* 2006, Gueddouda *et al.* 2006-2007). These solutions have been developed to minimize the pressures on soil saturation.

The work presented in this paper is a contribution to the application of chemical stabilization techniques, by adding salt (NaCl) for different concentrations lime, cement, association lime + cement, and association of lime and salt for Three different clays, two clays belonging to different arid regions of southern Algeria and a very expansive clay known as Bentonite Maghnia (in the region of Tlemcen), where several cases were reported disorders characterized by cracks in the superstructure and the foundation level.

Initially, the chemical, physical and geotechnical properties of the untreated soils were determined. These tests were complemented by direct measurements of the swelling parameters (free swell and swell pressure). Secondly, the study examined the effects of different types of stabilization on the physical properties and the swelling parameters.

II. Materials Used for Study

a) Localization of the soils

The first soil is extracted from an area located 20 km northwest of the city of Laghouat (Basis of Life, Pumping Station No. 5); this region is considered semi-arid to arid, located 400 km south of the capital Algiers (Fig. 1). From the geological point of view, this zone presents several layers of which the first is covered with a vegetable layer a thickness of approximately 30 cm

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followed by a layer of silt and sandy-gritty, finally a layer of greenish and reddish marls with presence of gypsum crystals at a depth of over 1m. Our sample is extracted at a depth of 3.5 m (3rd layer). This soil is named ELG.

The second soil extracted from the In-Amenas region, this region is considered arid to very arid region located 1600 km south of the capital Algiers (Fig.1). Several studies have been conducted on this soil. The synthesis of these studies shows that the clays in this region occur along a stratigraphic fairly regular succession according to different layers. A sandy cover of about ten centimetres, an upper layer consists of silty clay material reddish color and a thickness of 1.5 m, a compact clay layer of darker color than the upper layer, and finally a layer greenish are relatively thin soil (Tas 1992, Kaoua and Derriche 1994, Derriche and Kebaili, 1998). The soil studied was extracted in the third layer. This soil will be named (EAM).

The term 'Bentonite' is now well established, and used to describe a clay material whose major mineralogical components belong to Smectite groups. As a result, bentonite is a very expansive soil. The most important bentonite mines in Algeria are situated in the western regions (Fig. 1). The bentonite used in this study is extracted from Maghnia mine (Hammam Boughrara, 600 km west of the capital Algiers).

b) Characterization of the soils

The physical characteristics of the untreated soil are shown in Table 1. All geotechnical tests were performed in accordance with British Standard 1377. Based on Casagrande plasticity chart, this soil ELG and EAM was classified as of high plasticity clay. These soils showed a high plasticity index 35% and 40% respectly and an activity of 1 and 0.75 respectly. The bentonite of Maghnia it is very fine clay; more than 60% of particles have a diameter less than 2 μm. The value of the liquidity limit and Plasticity Index LL= 141%, PI = 93% respectly; indicate that the bentonite of Maghnia is highly plastic clay, this is also confirmed by a large specific surface (Ss = 462 m^2/g). According to the Skempton classification (Skempton 1953), based on the activity (Eq. (1)), the bentonite of Maghnia presents a high percentage of calcite Montmorillonite (Ca^{+2}).

Generally, the higher the plasticity index and activity of a soil, the higher the swelling potential. According to the Van der Merwe (1975) classification system, the soil was classified as having high swelling potential.

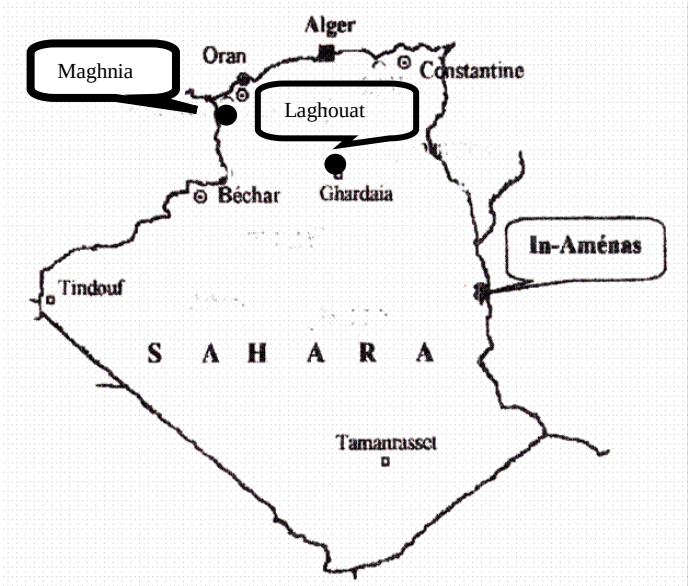

Figure 1: Localization of the soils

Table1 : Physical characteristic of the soils

	%<2μ	LL (%)	PI (%)	LS (%)	A	γ_d (kN/m³)	w_{opt} %	Sst (m^2/g)
ELG	36	69	35	12	1	17.8	15	189
EAM	55	62	40	13	0.7	18	13	437
B	60	141	93	9	1.55	12	34	462

$$\text{Activity}: A = \frac{IP}{\%<2\mu m} \qquad (1)$$

The mineralogical and chemical of the untreated soil are shown in Table 2. From chemical analysis, the main mineralogical constituents of the three soils are silica and alumina. For soil ELG, the presence of high percentage of calcium carbonate (CaO) indicates to us that this ground belongs to the group of clays limestones. The potassium K_2O content in soil EAM confirms the presence of Illite. Moreover, we note that the three soils present percentages in SiO_2 lower than 80%, boundary value between the swelling soil and not swelling soil (Hachichi and Fleureau 1999) which predicts that these soils have a natural tendency to swell. X-ray diffraction is one of the most widely used methods for clay minerals identification and studying their crystal structure within the soils. Diffraction test carried out on bentonite, showed that the predominant clay minerals are smectic types; beside it reveals also the presence of Illite, quartz, and traces of kaolinite.

Table 2 : Chemical analysis of soil

%	SiO_2	Al_2O_3	Na_2O	CaO	K_2O	MgO	Fe_2O_3	M.O
ELG	58.94	10.03	0.35	17.70	2.01	0.7	1.02	9 .56
EAM	56.3	15.12	2.36	2.56	2.4	1.43	7.0	12.83
Bentonite	65.2	17.25	3	5	1.7	3.1	2.1	2.65

III. Study of Swelling Clays

a) Estimation of swelling potential

A considerable number of empirical approaches proposed by different authors are used to evaluate the swelling potential. These approaches are based on physical characteristics of soil (LL, PL, PI, C_2); Skempton 1953, Seed *et al.* 1962, Ranganathan and Satyanaryana 1965, Vijayverjya and Ghazzaly 1973, Williams and Donaldson 1980, Mouroux *et al.* 1988, Holtz and Gibbs 1996. However, models for predicting swelling are rude. Direct measurements of swelling parameters are needed to confirmed and quantify the swelling of clay. Generally, all classifications show that soils ELG and EAM tended a high rate of swelling, while for Bentonite; it has a very high rate of swelling, which in agreement with the mineral montmorillonite is predominant.

b) Direct Measurement of swelling parameters

Many researchers have used the term swelling potential. However, a clear definition of the term has not been established. Generally, swelling potential has been used to describe the ability of a soil to swell, in terms of volume change or the pressure required to prevent swelling. Therefore, it has two components: the swell percent which is defined as the percentage increase in height in relation to the original height, and the swell pressure which is designated as the pressure required to prevent swelling.

i. *Measurement of swelling potential*

Swelling tests are carried out using a standard one-dimensional oedometer. Dimensions of samples are 50 mm in diameter and 20 mm in height. The test is realized according to the free swelling method (Serratrice and Soyez 1996)). The soils samples are prepared by a static compaction (velocity of 1 mm/min) for water contents and dry densities corresponding to the Optimum Proctor Conditions. The sample is placed in a cylindrical cell between two porous stones. Then, by imbibition, it is authorized to swell vertically under the pressure of the piston during several days until stabilization. The total free swelling (G %) is computed using the following relationship (Eq. 2) :

$$G\ (\%) = \frac{(Hf - H0)}{H0} \times 100 \qquad (2)$$

$\Delta H = H_f - H_0$

H_0: initial height (before swelling)

H_f : final height (after swelling)

ii. *Measurement of swell pressure*

Two methods to measure the swelling pressure to the œdometer were used:

- Method of free swelling: After the free phase of swelling under weak load (weight of the piston), the quasi saturated sample follows a way of loading until its volume returns to its initial value. The corresponding constraint is the swelling pressure (Chen 1988).
- Method of constant volume: this method is carried out according to standard ASTM D 4546-90 (American Society for Testing and Materials). It consists in neutralizing the swelling of the sample by the application of an increasing load as soon as the displacement of the comparator reaches 1/100 mm. The addition of loads was continued until deformation ceased. At this stage, the value of the load when the sample is stabilized represents the swelling pressure (Chen 1988, Serratrice and Soyez 1996).

c) Results

Figure 2 shows the evolution of free swelling (G %) according to time for the three soils. It is noted that during the imbibition, the swelling soil in a similar way. The evolution of free swelling presents two phases: primary swelling where the evolution is fast and a secondary swelling where the evolution is less slow. In general, after 7 days, the swell percent are of 20% for the soil of Laghouat (ELG) and from approximately 30% for the soil of In Amenas (EAM). The bentonite present a very important swell percent, it about 70% (Gueddouda *et al.* 2010). The obtained results show the swell character of the soils and confirm the observations obtained using the indirect methods.

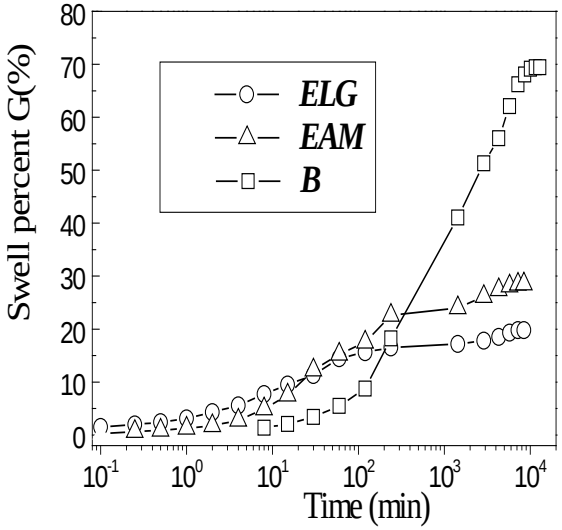

Figure 2 : Swelling evolutions of soils versus time

The results of swell pressures summarized in Table 3. It is noted that the three soils develop very significant swell pressures. The bentonite of Maghnia swell pressure develops a very important; it is of the order of 900 kPa. For soils ELG and EAM, the swell pressures are about 400 and 480 kPa respectively.

Moreover, we note that the swelling pressure determined by the method of free swelling is higher than that obtained by the method of constant volume. This is consistent with the results given by Sridharan *et al.* 1986, Philipponnat and Huber 1997. This difference is attributed to the friction that develops during the recompression phase of the sample after free swelling.

Table 3 : Results of swelling parameters

	G%	Ps_1 (kPa)	Ps_2 (kPa)	Ps (kPa)
ELG	19.8	412.5	400	406
EAM	28.5	585	370	477
B	70	960	840	900

G% : free swell
Ps_1 : swell pressure (method of free swelling)
Ps_2 : swell pressure (method of constant volume)
Ps : Medium swell pressure

IV. Chemical Stabilization of Soils

The products used for the stabilization of the three soils are: salt, Lime and cement.The salt used is NaCl. Salt solutions (distilled water + NaCl) with the following concentrations: 0.1 M, 0.5 M and 1.5 M (M is the molality of the salt solution (M = mol / liter)).The lime used is that of the region of Saida and is a hydrated lime presenting a low concentration of elements such as silicates oxides SiO_2 (< 2%), Al_2O_3 and aluminates (< 1%) and a high concentration of basic elements as a free lime CaO (< 70%). The concentrations used are: 2%, 4% and 6%.The cement used is Portland cement composed (CPJ-CEM II / A) 42.5. The cement is fabricated of M'sila and available on the market. The concentrations used are: 2%, 4% and 6%.The preparation is made by cementing a substitution capacity of water by the percentages of lime or cement. For lime + water, the curing period is 24 hours, by cons for cement + water is immediate. The samples were prepared by static compaction at the OPN. The swelling potential is determined by the same methods used for soil untreated with imbibition saline and hydraulic binders.

a) Stabilization of clays by salts, lime and cement

The liquid limit and plasticity index of the untreated and treated samples are shown in Table 4. Hydraulic binders (cement or lime) conduct to lower liquid limits and plasticity index. Reductions in plasticity indices are important and can reach 60% for soils EAM and ELG for a percentage of 6% lime. The effects of hydraulic binders on bentonite are lower compared with soils ELG and EAM. The limits of liquidity reach a reduction of about 25% for a percentage of 6% lime. Generally, the effects of lime and cement are similar. This behavior is attributed to the cations exchange process between the cations of the soil and those of the stabilizers. The effect of salt (NaCl) leads to greater reductions in the limits of consistencies that hydraulic binder. The reductions reach about 75% for a concentration of 1.5 M.

Swell percent and swell pressure tests were carried out on untreated samples to measure these two parameters in order to examine the effect of the various additives on the reduction of the swelling potential of the soil Figure 3 shows the evolution of free swelling (G%) versus time for three soils with different types of stabilization. The swelling pressures of untreated and treated soils are summarized in Table 4. The swelling pressure shown is the medium of the swelling pressures obtained by two methods.

- Action of salt (NaCl) : Examination of the curves of evolution of free swelling as a function of time indicates that the reduction rate of free swelling by saline is proportional to the concentration of salt. For soils ELG and EAM and a low concentration of salt (0.1 M), reducing the swelling rate is only 20% and 18% for the swelling pressure. For a high concentration (1.5 M), reducing the swelling rate is around 60% and 80% for the swelling pressure. Moreover, we note that for a low concentration of 0.1 M, the reduction of swelling bentonite is about 40% and about 70% to swelling pressure, while for concentration of 1.5 M, reductions in swelling parameters are more important, it attains a reduction of more than 90% for the swelling pressure. It can be concluded that salt (NaCl) is more effective in reducing the swelling pressure as the rate of swell. These results are in good agreement with results obtained by Nalbantoglu 2001, Abu Baker *et al.* 2004, Bekkouche *et al.* 2007.
- Action of lime and cement : Increased percentage

of lime and cement can reduce the swelling rate. For 6% lime, reducing the swelling rate can reach 70%. Similarly for cement or reduction is greater than 60%. The effect of lime appears to be important that the effect of cement. The same findings are obtained for the swelling pressure or the reduction exceeds 80%. For the same percentage of 6% lime, the swelling pressure of bentonite from 900 kPa to 135 kPa. For the EAM ground, it decreases from 477 kPa to 81 kPa for soil ELG; it goes from 406 kPa to 40 kPa. In general, the actions of lime and cement have similar effects on soil ELG and EAM, but the action of lime seems more important than that of cement to reduce the swelling pressure of bentonite. Lime affects the electric charges located around the clay particles and modifies the electric fields between the particles. When lime is added to clay soils in the presence of water, a number of reactions occur leading to the improvement of soil properties. These reactions include cations exchange, flocculation, carbonation and pozzolanic reaction. The cations exchange takes place between the cations associated with the surfaces of the clay particles and calcium cations of the lime. The effect of cations exchange and attraction causes clay particles to become close to each other, forming flock; this process is called flocculation. Flocculation is primarily responsible for the modification of the engineering properties of clay soils when treated with lime (Bell 1996, Al-Rawas 2002, Djedid *et al.* 2005). Cement stabilization is similar to that of lime and produces similar results. Cement stabilization develops from the cementations links between the calcium silicate and aluminate hydration products and the soil particles. When adding cement, cement powder moistened her in contact with moist soil and form a paste that coats the lumps. Cement is a cementing agent, it binds the particles together causing the stiffening of the soil and therefore it leads to reduced swelling parameters (Sherwood 1995, Nalbantoglu *et al.* 2001).

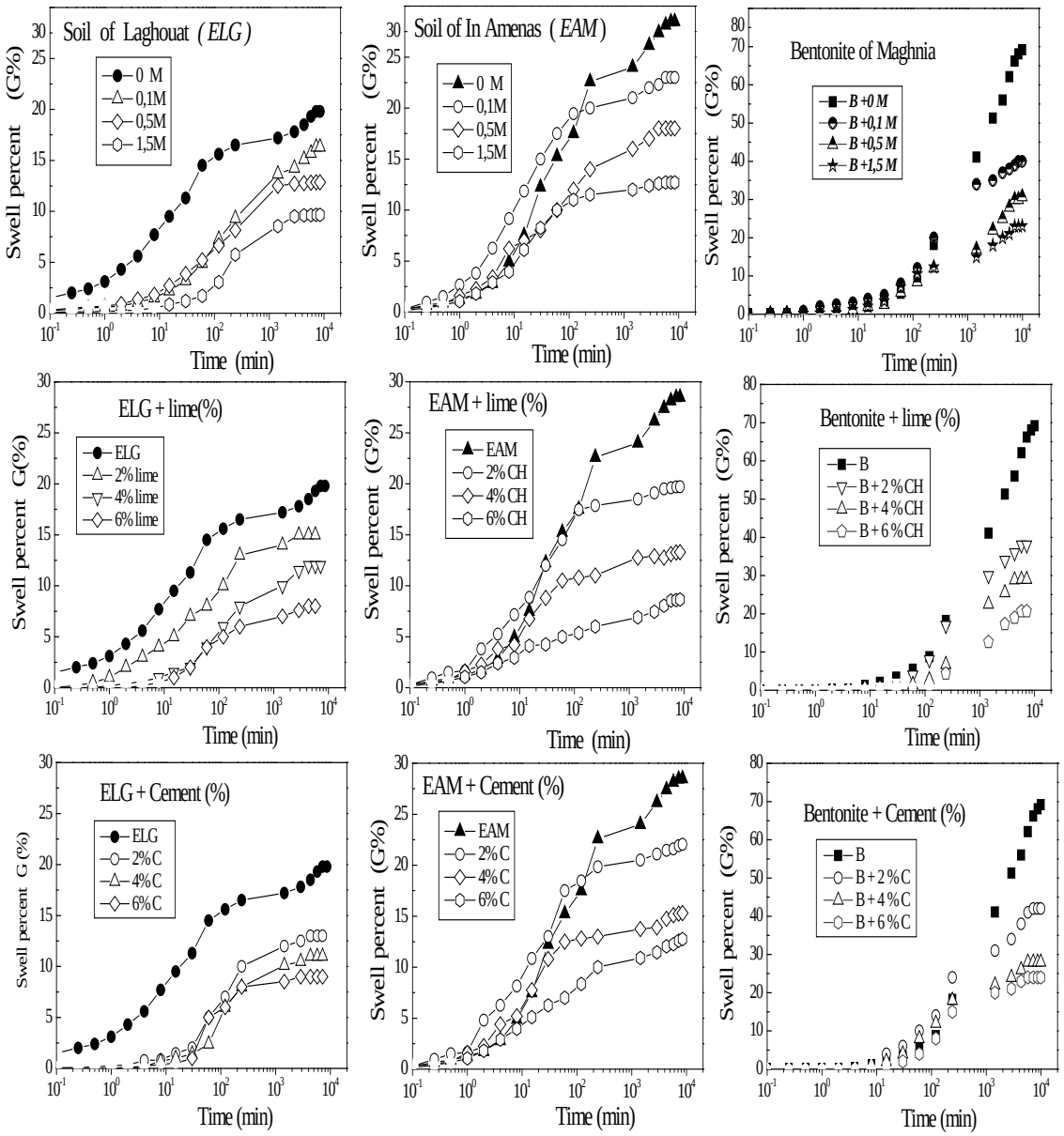

Figure 3 : Evolution of free swelling (G %) versus time for three soils with different types of stabilization

Table 4 : Geotechnical results of the treated samples

		LL	PI	G (%)	ΔG /G (%)	Ps (kPa)	ΔPs/Ps(%)
	B	141	93	70	---	900	---
	EAM	62	40	29	----	477	---
	ELG	69	35	20	---	406	---
Salt (NaCl)	B + 0.1 M	70	38	40	42	260	70
	B + 0.5 M	65	34	30	57	180	80
	B + 1.5 M	50	25	23	67	80	91
	EAM + 0.1 M	58	34	23	20	390	18
	EAM + 0.5 M	41	21	18	38	228	52
	EAM + 1.5 M	20	15	13	56	120	75
	ELG + 0.1 M	55	32	16	20	335	17
	ELG + 0.5 M	38	20	12	40	170	58
	ELG + 1.5 M	22	11	8	60	88	80
Lime	B + 2 %	134	88	38	45	700	21
	B + 4 %	108	59	29	58	485	65
	B + 6 %	103	53	21	70	135	85
	EAM + 2 %	53	35	20	31	286	40
	EAM + 4 %	37	22	13	56	133	72
	EAM + 6 %	24	12	9	70	81	83
	ELG + 2 %	63	23	15	25	250	37
	ELG + 4 %	32	8	12	40	80	81
	ELG + 6 %	20	6	8	60	40	90
Cement	B + 2 %	124	82	42	40	800	11
	B + 4 %	115	73	28	60	504	44
	B + 6 %	110	59	24	66	324	64
	EAM + 2 %	50	32	22	25	340	28
	EAM + 4 %	39	24	15	48	130	72
	EAM + 6 %	31	14	13	56	85	82
	ELG + 2 %	45	25	13	35	280	31
	ELG + 4 %	32	19	11	45	77	81
	ELG + 6 %	29	10	9	55	57	86

b) Combination Stabilization

The Combination soil stabilization used is the combination of lime and cement for different percentage (2% Lime + 2% Cement; 2% Lime + 6% Cement; 6% Lime + 2% Cement; 6% Lime + 6% Cement). Figure 4 shows the evolution of free swelling (G %) versus time for three soils for different types of stabilization combined. The effect of combining lime + cement on the swelling ratio is shown in Fig. 5. Reducing the rate of swelling is around 70% for a combination of 6% lime and 6% cement. In general, the action of the combination of lime and cement conduit to effects similar to those of one lime or cement alone. This result is in good agreed with those found by Al-Rawas *et al.* 2005.

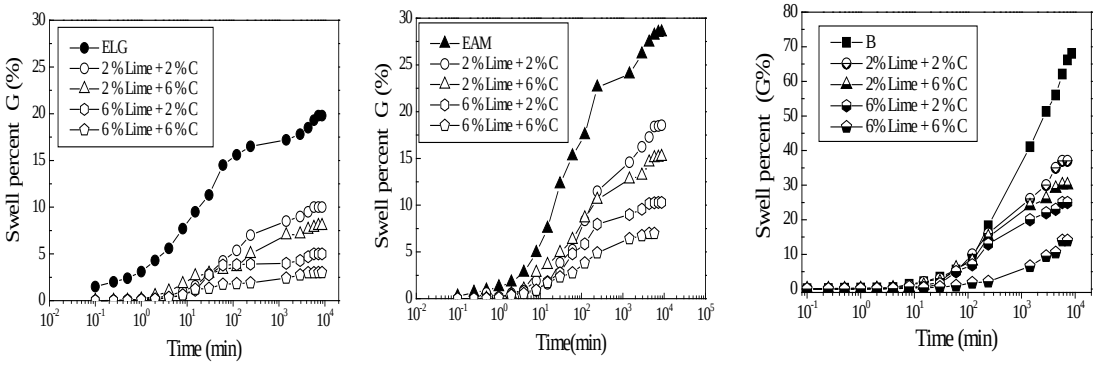

Figure 4 : Evolution of free swelling (G %) versus time for three soils with different types of stabilization Combination

A second type of Combination stabilization has been used for bentonite. It is the combination of lime and salt NaCl. The different combinations are used: 2 % Lime + 0.1 M ; 2 % Lime + 1.5 M ; 6 % Lime + 0.1 M; 6 % Lime + 1.5 M. Figure 5 shows the evolution of free swelling (G%) versus time. For a combination of 2% + 0.1 M CH, reducing the swelling rate is around 50%. For a combination of 6% Lime + 1.5 M, the reduction is about 80%. Figure 6 shows the evolution of swelling pressure versus time by the method of constant volume. For a combination of 6% Lime + 1.5 M, swelling pressure passes for 900 kPa to 50 kPa, a reduction is more than 95%. This stabilization method seems more effective in reducing the swelling pressure as the free swell.

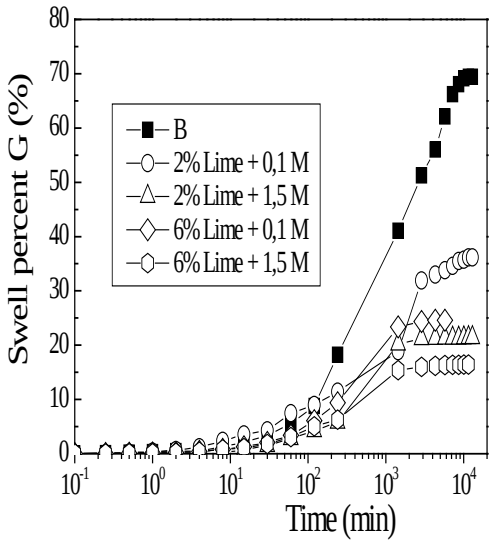

Figure 5 : Evolution of free swelling (G %) versus time for three soils with different types of stabilization Combination (lime + salt)

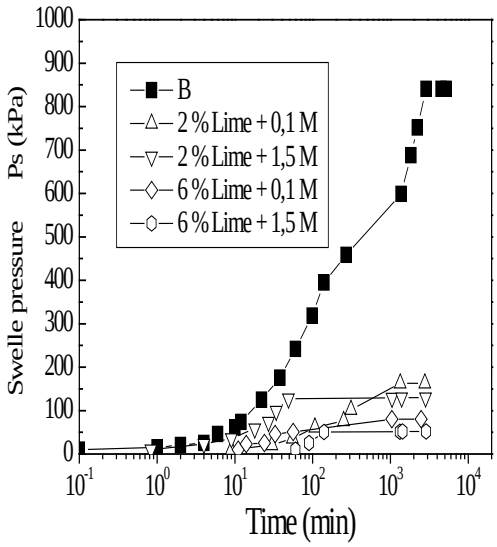

Figure 6 : Evolution of swelling pressure (Ps) versus time for three soils with different types of stabilization Combination (lime + salt)

V. Conclusions

This paper evaluated the effect of salt, lime, cement, combinations of lime and cement, and combinations of lime and salt on the swelling potential of Algeria expansive soil. Addition of lime to clay soil reduces the liquid limit, plasticity index and swelling potential. Cement stabilization is similar to that of lime and produces similar results. Chemical stabilization by saline containing NaCl seems less effective. For a 1.5 M concentration, reducing the swelling potential is less than 70%. The salts are more effective in reducing the swelling pressure as the magnitude of swelling Stabilization combined lime + cement gives satisfying results when the reduction of swelling parameters can attain 70%. The action of the combination of lime and cement conduit to effects similar to those of alone lime or cement alone. Stabilization combined lime + salt, the results is better than the combined lime + cement stabilization. For a combination of 6% lime + 1.5 M, reduction of swelling parameters is of the order of 80 for the free swell and more than 95% for the swelling pressure.

Generally, all stabilizers caused a reduction in both swell pressure and swell percent. Finally, the abundance of the two materials (lime and salt) at reasonable prices in the region. We can advance of the technique of combined stabilization (lime + salt) an alternative economical and effective for the treatment of swelling clays.

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Analysis of A Dual Band Micro strip Antenna

By S B Kumar

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Abstracts - In modern wireless communication systems andincreasing other wireless applications, wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. Since the microstrip antenna has its various advantages like low profile, small size, inexpensive cost and ability to be integrated with VLSI design. The current paper proposes a simple, methodical approach to design a microstrip antenna. Where the antenna behaviors are investigated. Simulation result of this antenna shows a dual band with little wider band width. From the return loss plot, it is concluded that a single antenna has two resonance frequencies, which are at 5.2Ghz and 7.69Ghz.Operating frequency of proposed antenna is 5.2 Ghz. Traditionally, each antenna operates at a single or multi frequency bands, where different antenna is needed for different applications. In addition to the theoretical design procedure, numerical simulation was performed using Methods of Moments and IE3D software.

Index Terms : *Microstrip antenna, VSWR, Return loss, Radiation pattern.*

GJRE-J Classification : *FOR Code: 100501*

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I. Introduction

The first idea to use micro strip antenna begin since beginning of 1950's and design concept introduce by Deschamps. Several years later, Gutton and Baissinot have patent the basic micro strip antenna. It was first published in 1952 by Grieg and Englemann.Figure 1.1 show the basic structure of micro strip antenna which consists of radiating patch, dielectricsubstrates and ground plane. Bottom layer of dielectric substrate is fully covered by conductors that act as a ground plane[1]. The thickness of substrates layer can increase the bandwidth and efficiency, but unfortunately it will generate surface wave with low propagation that cause lost of power. There are several approaches to analyze micro strip antenna. Among the favorite are transmission line, cavity model, and full-wave analysis. Transmission line model are the simplest way of analysis and the most precisely method for analysis is full-wave model, but it need to go through difficult process.

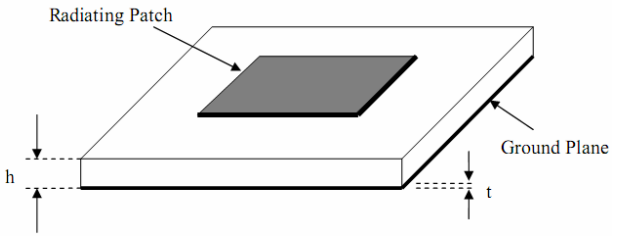

Figure 1.1 : Basic structure of micro strip antenna.

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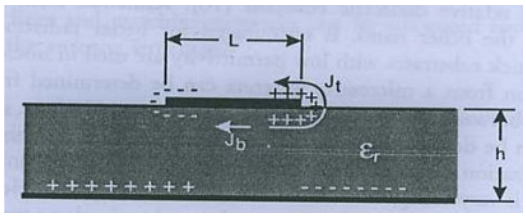

Figure 1.2 : Charge distribution and current density on a micro strip antenna

When a micro strip antenna is connected to a microwave source, it is energized. The charge distribution will establish on the upper and lower surfaces of the patch, as well as on the surface on the ground plane[2]. The positive and negative charge distribution then arises. Micro strip antennas have got high intention because of their good characteristics like :

Light

Cheap

Easily to integrate with other circuit Can be used widely in many applications both in commercial or military.Not needed complicated part.

However there are several weaknesses or disadvantages of using micro strip antennas :

Narrow bandwidth

Low gain

Surface wave excitation

Low efficiency

Low power handling capacity

a) Antenna Properties

The performance of the antenna is determined by several factors that also called antenna properties as follows.

i. *Input Impedance*

Generally, input impedance is important to determine maximum power transfer between transmission line and the antenna. This transfer only happen when input impedance of antenna and characteristic impedance of the transmission line are matched. Otherwise reflected wave will be generated at the antenna terminal and travel back towards the energy source, reducing system efficiency. The input impedance is given by

$$Z_{in} = Z_0\left(\frac{1+S_{11}}{1-S_{11}}\right)$$

ii. *VSWR*

Voltage Standing Wave Ratio (VSWR) is the ratio between the maximum voltage and the minimum

voltage along transmission line. The VSWR, which can derive from the level of reflected and incident waves, is also an indication of how closely or efficiently an antenna's terminal input impedance is matched to the characteristic impedance of the transmission line. Increasing in VSWR indicates an increase in the mismatch between the antenna and the transmission line. A decrease VSWR means good matching with minimum VSWR is one. The VSWR is given by:

$$VSWR = \frac{1+S_{11}}{1-S_{11}}$$

iii. *Bandwidth, BW*

The term bandwidth simply defines the frequency range over which an antenna meets a certain set of specification performance criteria. The important issue to consider regarding bandwidth is the performance tradeoffs between all of the performance properties described above. There are two methods for computing an antenna Bandwidth. An antenna is considered broadband if fH/fL_2.

Narrowband by %

$$BWp = \frac{f_H - f_L}{f_o} \times 100\,\%$$

Broadband by ratio

$$BWb = \frac{f_H}{f_L}$$

Where f_o = operating frequency
f_H = higher cut - off frequency
f_L = lower cut - off frequency

iv. *Polarization*

The polarization of an antenna describes the orientation and sense of the radiated wave's electric field vector i.e behavior of electromagnetic wave.

There are three types of basic polarization:

linear polarization
elliptical polarization
circular polarization

Generally most antennas radiated with linear or circular polarization. Antennas with linear polarization radiated at the same plane with the direction of the wave propagate. For circular polarization, the antenna must radiate in circular form.

v. *Radiation Pattern*

The radiation patterns of an antenna provide the information that describes how the antenna directs the energy it radiates. All antennas, if are 100% efficient, will radiate the same total energy for equal input power regardless of pattern shape. Radiation patterns are generally presented on a relative power dB scale. It can be shown on 360 degree polar plot. Example of radiation pattern is shown in Figure 2.2.1. In many cases, the convention of an E-plane and H-plane pattern is used in the presentation of antenna pattern data. The E-plane is the plane that contains the antenna's radiated electric field potential while the H-plane is the plane that contains the antenna's radiated magnetic field potential. These planes are always orthogonal.

II. Antenna Design

In this paper, a microstrip transmission line feeding patch antenna design is presented .This antenna has basic parameters Dielectric Constant, Epsr = 3.2, operating frequency fo= 5.2 GHz, thickness of substrate h= 1.57mm and loss tangent equal to 0.001. Simulation for the basic patch with transmission line feeding resulted in antenna size of length 15.04mm and width 20.85 mm. Proposed antenna was design using ie3d software.

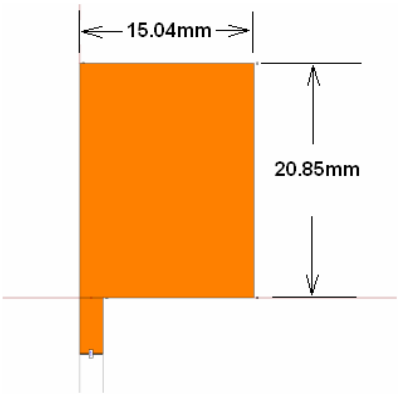

Figure 2 : Microstrip transmission line feed patch antenna.

Figure 2 shows simple patch antenna of transmission line feeding which has resonance fo=5.2GHz.

a) Simulation Results

i. *Return loss Result*

When the basic patch the dimensions as mentioned in Figure2.when the Sierpinski Carpet Antenna is simulated. The simulation results with a feed of 2mm width by 5mm length are as shown by the Figure 2.2.1,

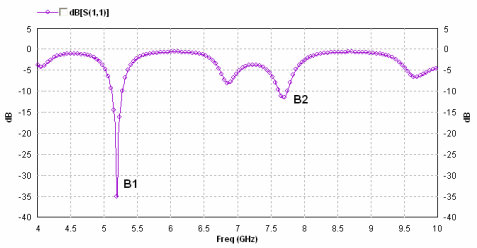

Figure 2.1.1 : Return loss of the patch

Band	f (GHz)	S_{11} (dB)	BW (MHz)	Antenna Efficiency (%)
B1	5.20	- 35.2	173.44	78.41
B2	- 7.69	11.69	146.09	56.36

Table 2.1.1 : Return loss of the patch

There exist two possible frequency bands for operation that have return loss less then 10dB; one centered at 5.2GHz and another at 7.7GHz. The band B2 does not has good return loss but has a quit wide bandwidth below -10dB or VSWR less then 2.

b) Radiation Patterns

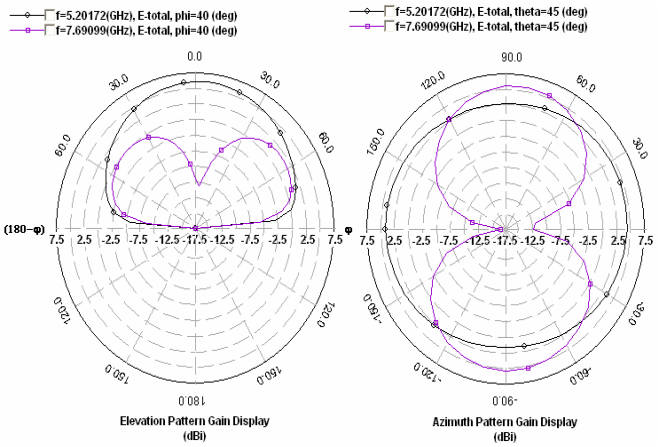

Figure 2. 3.1 : Radiation pattern for dual band microstrip antenna at B1 & B2.

III. Conclusion

From results and discussions, it can be concluded that:We can define the microstrip antenna with transmission line feed.A single antenna work on two band as shown in the simulated result. With this property, simulated antenna is called dual band antenna. This work can be extended to the multi –band behavior of the antenna using fractal shape.

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Voltage Level Improving by Using Static VAR Compensator (SVC)

By Md M. Biswas, Kamol K. Das

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Abstracts - This paper presents the potential applications of flexible AC transmission system (FACTS) controllers, such as the static VAR compensator (SVC), using the latest technology of power electronic switching devices in the fields of electric power transmission systems with controlling the voltage and power flow, and improving the voltage regulation. Again, the static VAR compensators are being increasingly applied in electric transmission systems economically to improve the post-disturbance recovery voltages that can lead to system instability. A SVC performs such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with high-tech power electronic switching devices. This work is presented to solve the problems of poor dynamic performance and voltage regulation in an 115KV and 230KV transmission system using SVC.

Keywords : *Static VAR compensator (SVC), thyristor controlled reactor (TCR), automatic voltage regulator (AVR), voltage regulation, Simulink.*

GJRE-J Classification : *FOR Code: 090699*

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I. Introduction

Day by day, demands on the transmission network are increasing because of the increasing number of non utility generators and heightened competition among utilities themselves. Increased demand on transmission system, absence of long term planning and the necessity to provide open access to power generating companies and customers; all together have created tendencies toward a reduction of security and decreased quality of supply.

The AC power transmission system has diverse limits, classified as static limits and dynamic limits [1]-[3]. These inherent limits restrict the power transaction, which lead to the under utilization of the existing transmission resources. Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to solve much of these problems. However, there are some restrictions as to the use of these conventional devices. Desired performance was being unable to achieve effectively. Wear and tear in the mechanical components and slow response were the major problems. As a result, it was needed for the alternative technology made of solid state electronic devices with fast response characteristics. The requirement was further fuelled by worldwide restructuring of electric utilities, increasing environmental and efficiency regulations and difficulty in getting permit and right of way for the construction of overhead power transmission lines [4]. This, together with the invention of semiconductor thyristor switch, opened the door for the development of FACTS controllers.

The path from historical thyristor based FACTS controllers to modern technologically advanced voltage source converters based FACTS controllers, was made possible due to rapid progress in high power semiconductors switching devices [1]-[3]. A static VAR compensator (SVC) is an electrical device for providing fast-acting reactive power compensation on high voltage transmission networks and it can contribute to improve the voltages profile in the transient state and therefore, in improving the quality performances of the electric services. A SVC is one of FACTS controllers, which can control one or more variables in a power system [5]. The dynamic nature of the SVC lies in the use of thyristor devices (e.g. GTO, IGCT) [4]. The thyristor, usually located indoors in a “valve house”, can switch capacitors or inductors in and out of the circuit on a per-cycle basis, allowing for very rapid superior control of system voltage.

The compensator studied in the present work is made up of a fixed reactance connected in series to a thyristor controlled reactor (TRC) based on bi-directional valves- and a fixed bank of capacitors in parallel with the combination reactance-TRC. The thyristors are turned on by a suitable control that regulates the magnitude of the current.

II. Static VAR Compensator

a) Configuration of SVC

SVC provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled devices [6]. A SVC is typically made up of coupling transformer, thyristor valves, reactors, capacitance (often tuned for harmonic filtering).

b) Advantages of SVC

The main advantage of SVCs over simple mechanically switched compensation schemes is their near-instantaneous response to change in the system

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voltage. For this reason they are often operated at close to their zero-point in order to maximize the reactive power correction [7]-[10]. They are in general cheaper, higher-capacity, faster, and more reliable than dynamic compensation schemes such as synchronous compensators (condensers). In a word:

1) Improved system steady-state stability.
2) Improved system transient stability.
3) Better load division on parallel circuits.
4) Reduced voltage drops in load areas during severe disturbances.
5) Reduced transmission losses.
6) Better adjustment of line loadings.

c) Control Concept of SVC

An SVC is a controlled shunt susceptance (B) as defined by control settings that injects reactive power (Q) into the system based on the square of its terminal voltage. Fig. 1 illustrates a TCR SVC, including the operational concept. The control objective of the SVC is to maintain a desired voltage at the high-voltage bus. In the steady-state, the SVC will provide some steady-state control of the voltage to maintain it the high-voltage bus at a pre-defined level.

If the high-voltage bus begins to fall below its set point range, the SVC will inject reactive power (Q_{net}) Into thereby increasing the bus voltage back to its net

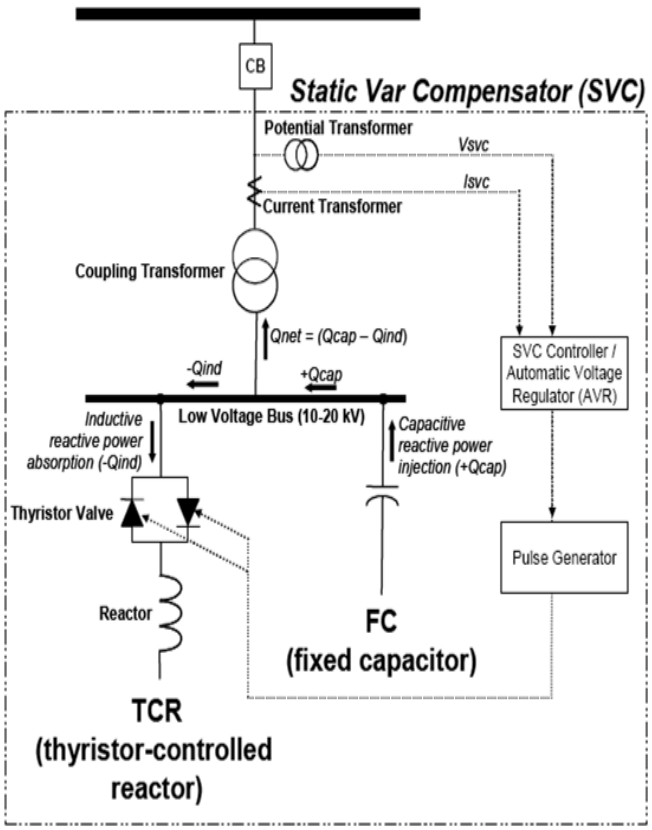


Fig.1 : SVC with control concept.

desired voltage level. If bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power, and the result will be to achieve the desired bus voltage. From Fig. 1, $+Q_{cap}$ is a fixed capacitance value, therefore the magnitude of reactive power injected into the system, Q_{net}, is controlled by the magnitude of $-Q_{ind}$ reactive power absorbed by the TCR. The fundamental operation of the thyristor valve that controls the TCR is described here. The thyristor is self commutates at every current zero, therefore the current through the reactor is achieved by gating or firing the thyristor at a desired conduction or firing angle with respect to the voltage waveform [11].

III. The Thyristor Controlled Reactor

The basis of the thyristor-controlled reactor (TCR) is shown in Fig. 2. The controlling element is the thyristor controller, shown here as two oppositely poled thyristors which conduct on alternate half-cycles of the supply frequency. If the thyristors are gated into conduction precisely at the peaks of the supply voltage, full conduction results in the reactor, and the current is the same as though the thyristor controller were short-circuited.

a) Principle of Operation

The current is essentially reactive, lagging the voltage by nearly 90^0. It contains a small in-phase component due to the power losses in the reactor, which may be of the order of 0.5-2% of the reactive power. Full conduction is shown by the current waveform in Fig. 3(a). If the gating is delayed by equal amounts on both thyristors, a series of current waveforms is obtained, such as those in Fig. 3(a) through 3(d). Each of these corresponds to a particular value of the gating angle α, which is measured from a zero-crossing of the voltage. Full conduction is obtained with a gating angle of 90^0. Partial conduction is obtained with gating angles between 90^0 and 180^0. The effect of increasing the gating angle is to reduce the fundamental harmonic component of the current. This is equivalent to an increase in the inductance of the reactor, reducing its reactive power as well as its current. So far as the fundamental component of current

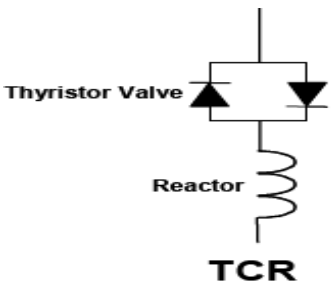


Fig. 2 : Elementary thyristor-controlled reactor (TCR).

is concerned, the thyristor-controlled reactor is a controllable susceptance, and can therefore be applied as a static compensator.

The instantaneous current i is given by,

$$i = \frac{\sqrt{2}V}{X_L}(\cos\alpha - \cos\omega t) \qquad \alpha < \omega t < \alpha + \sigma$$
$$= 0 \qquad \alpha + \sigma < \omega t < \alpha + \pi \qquad (1)$$

Where V is the rms voltage, $X_L = \omega L$ is the fundamental-frequency reactance of the reactor (in ohms), $\omega = 2\pi f$, and α is the gating delay angle. The time origin is chosen to coincide with a positive-going zero-crossing of the voltage. The fundamental component is found by Furier analysis and is given by,

$$I_1 = \frac{\sigma - \sin\sigma}{\pi X_L} V \qquad (2)$$

Where, σ is the conduction angle, and $\alpha + \sigma/2 = \pi$. We can write (2) as,

$$I_1 = B_L(\sigma)V \qquad (3)$$

Where $B_L(\sigma)$ represents an adjustable fundamental-frequency susceptance, which is controlled by the conduction angle according to the law,

$$B_L(\sigma) = \frac{\sigma - \sin\sigma}{\pi XL} \qquad (4)$$

This control law is shown in Fig. 4. For the full conduction in the thyristor controller that is with $\sigma = \pi$ or 180^0, the maximum value of B_L is obtained as $1/X_L$. The

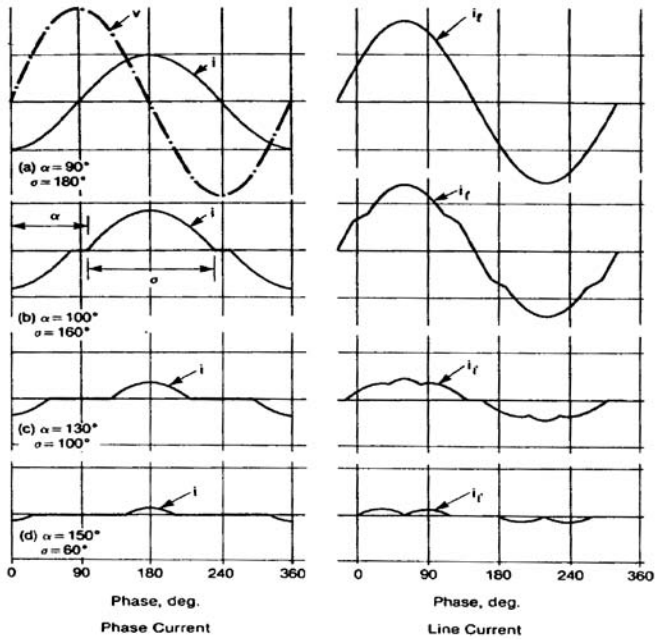


Fig.3 : Phase and line current waveforms in delta-connected TCR.

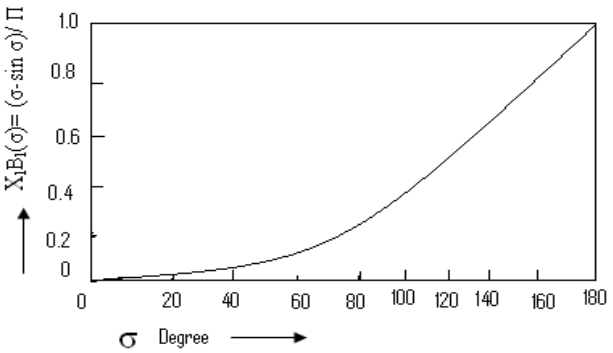


Fig. 4 : Control law of elementary TCR.

minimum value is obtained with $\sigma = 0$ ($\alpha = 180^0$) as zero. This control principle is called phase control.

IV. Performance Analysis of SVC Controller

a) Modeling for Dynamic Performance Analysis with SVC Applications

When studying system dynamic performance and voltage control, system modeling is an important aspect especially in and around the specific area of study. It is typical for many electric utilities to share large system models made up of thousands of buses representing the interconnected system. Details on modeling "system" elements such as transformers, generators, transmission lines, and shunt reactive devices (i.e. capacitors, reactors), etc., for short-term stability analysis are discussed. A significant and continually debated modeling aspect is the "load" model. For short-term stability analysis, loads are modeled with both static (e.g. real power, reactive power) and dynamic characteristics [12]. The automatic voltage regulator (AVR) control block is an important part of SVC models that operates on a voltage error signal. The generic AVR control block is defined by the transfer function as shown in Fig. 5.

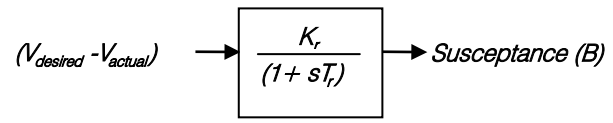


Fig. 5 : Transfer function of AVR control block.

Where K_r and T_r denotes the gain and time constant, respectively. The slope setting, maximum and minimum susceptance limits, thyristor firing transport lag, voltage measurement lag, etc are the additional commonly used control block functions of SVC dynamic models.

b) Controller Design Analysis

The SVC is operated as a shunt device to provide capacitance for voltage support or inductance to reduce the bus voltage. The fixed capacitors are

tuned to absorb the harmonics which are generated by the TCR operation. Although the SVC is capable of providing support for short-term stability and power oscillation damping, its major function is to provide voltage support and dynamic reactive power. A SVC in principal is a controlled shunt susceptance (+/-B) as defined by the SVC control settings that injects reactive power (+Q) or removes reactive power (-Q) based on the square of its terminal voltage. The block diagram is shown in Fig. 6.

In this application $Q=B\times V^2$, and L and C are components which are sized such that $Q \geq 0$ is the only operating range. The AVR in the form of proportional and integral control, operates on a voltage error signal

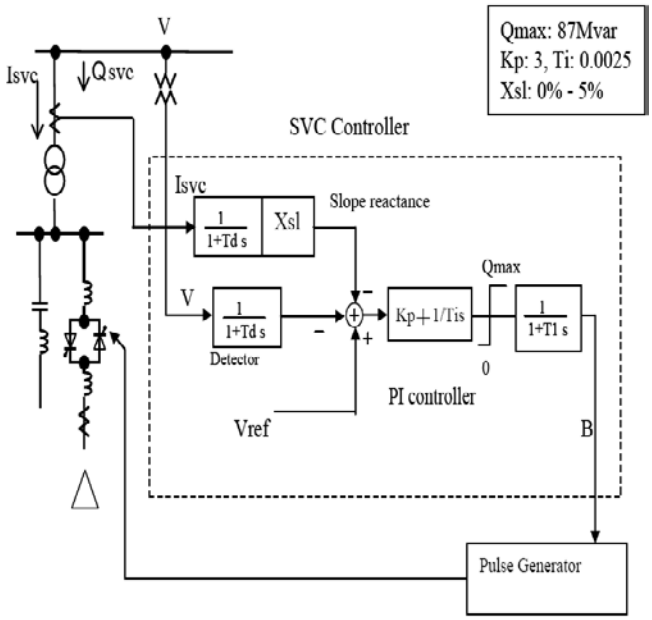


Fig. 6 : Detailed SVC block diagram.

$$V_{error} = V_{ref} - V - (I_{svc}X_{sl}) \quad (5)$$

There are also measurement lags (T_d) and thyristor firing transport lag (T_1). The output B of this control block diagram feeds into the pulse generator controller that generates the required thyristor firing signal for the light-triggered TCR.

c) Performance Criteria of SVC Operation

The control objective is to maintain the system voltage at 115 kV bus at 1.01 p.u. voltage. If the bus begins to fall below 1.01 p.u., the SVC will inject reactive power (Q) into the system (within its controlled limits), thereby increasing the bus voltage back to its desired 1.01 p.u. voltage according to its slope setting, X_{sl}. On the contrary, if bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power (within its controlled limits), and the result will be the desired bus voltage at bus [9]-[10]. The Simulink block diagram of SVC controller is given in Fig. 7.

The SVCs steady-state response will follow the voltage-current (V-I) characteristic curve shown in Fig. 8. The VI characteristic is used to illustrate the SVC rating and steady-state performance with the typical steady-state operating region being based primarily on the V_{ref}, X_{sl} setting, and the impedance of the system.

d) Typical Parameters of SVC

Table I : Typical parameters for SVC model

Parameter	Definition	Typical value
T_d	Time constant	.001-.005
T_1	Firing delay	.003-.006
X_{sl}	Slope reactance	.01-.05 pu

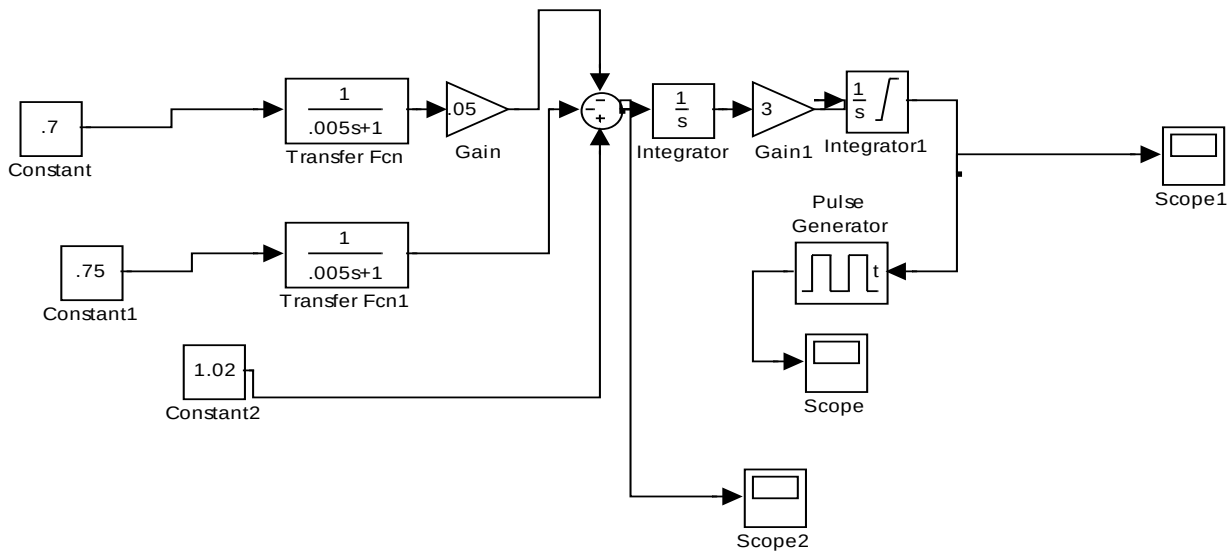


Fig. 7 : Simulink block diagram of SVC controller.

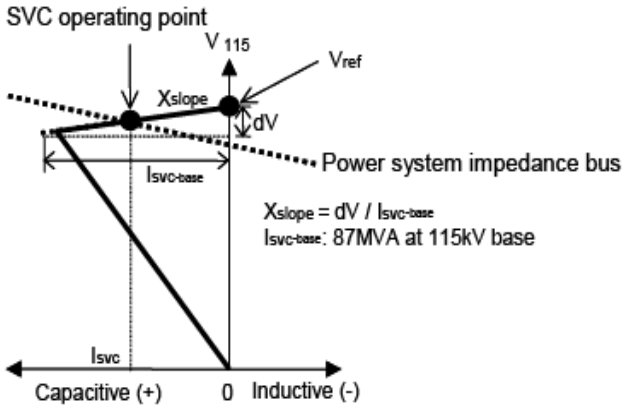
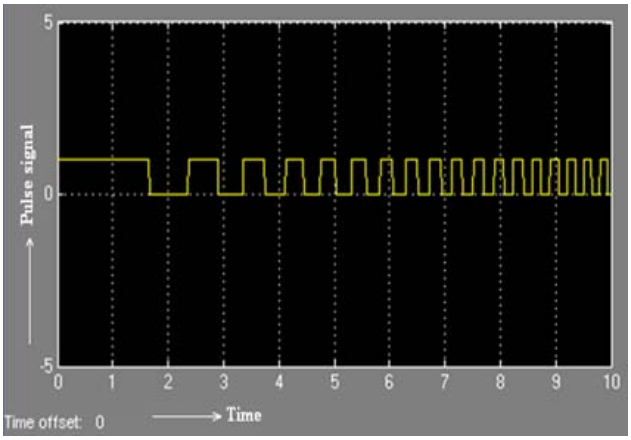
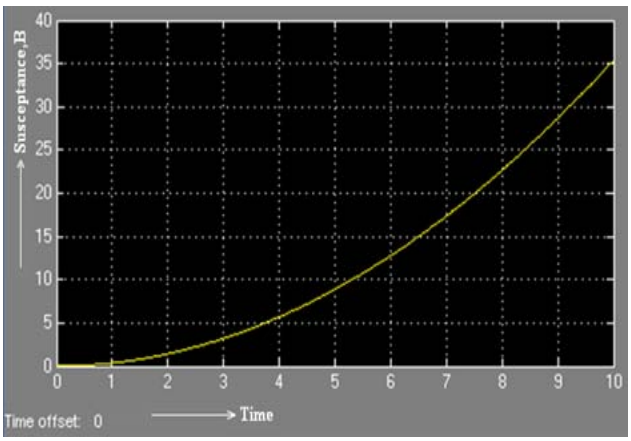


Fig. 8 : Steady state volt-current (V-I) characteristic of a SVC.

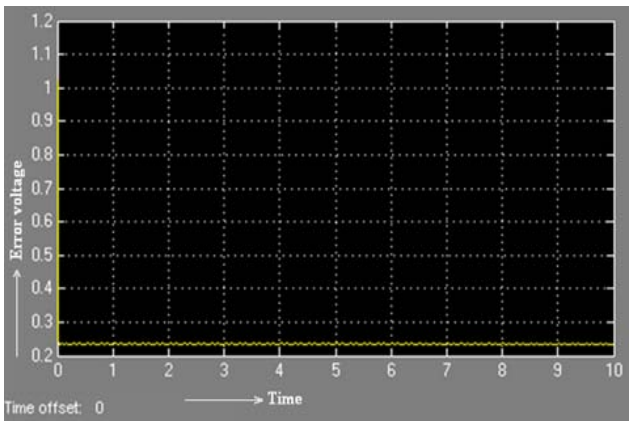
Scope : The required pulse.



Scope 1 : The susceptance which is increased due to drop of the bus voltage.



Scope 2 : The voltage error signal.



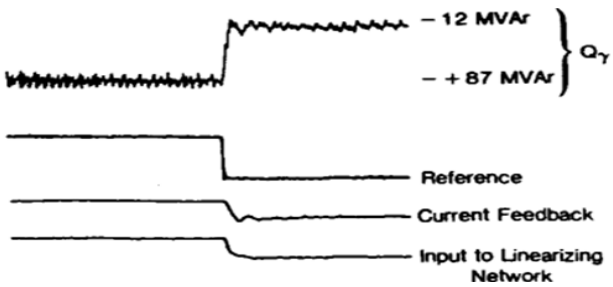
V. Modern Static VAR Compensator

In modern thyristor-controll edstatic compensator, the Rimouski compensator is installed on the transmission network of Hydro Quebec at 230 KV [6]-[7]. The compensator is typical of many such installations on high voltage transmission systems, but many of its design features are reproduced in load compensators also, particularly in supplies to electric arc furnaces. The Hydro Quebec system has many long distance, high voltage transmission lines. Prior to 1978 synchronous condensers were installed to provide reactive compensation. Planning studies, which considered various alternative forms of compensation, led to the decision to install two static compensators for performance evaluation, at locations not on the Baie James system [13]. One of these was installed near Rimouski, Quebec, on the 230-KV system of the Gaspe region. It was commissioned in 1978 and serves as a representative example of a transmission system compensator.

a) Performance Testing

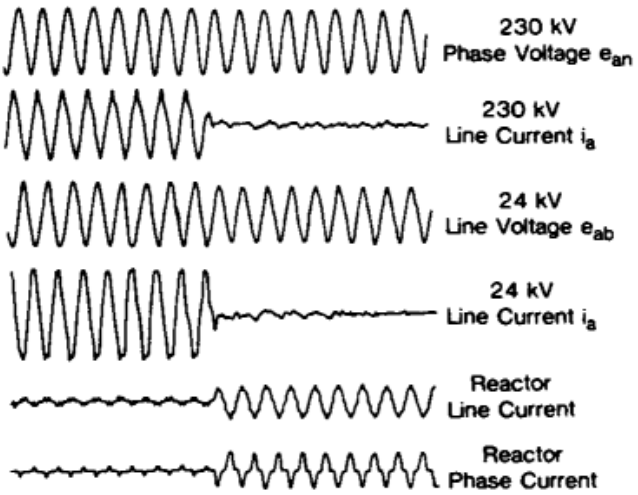
An extensive series of tests was made during and after commissioning to check the performance of the compensator. These tests included measurements of regular transfer function. The performance results are given below:

Case-1: Sudden change of - 99MVAR in response to a step change in reference signal as shown in Fig 9(a).



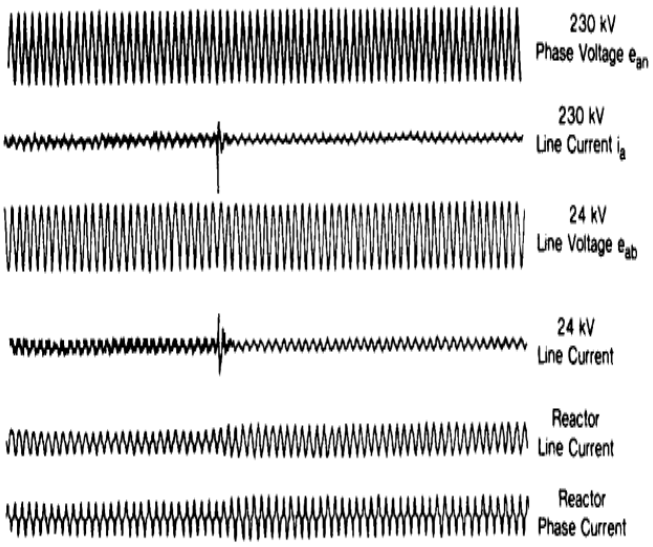
(a)

Case-2: Voltage and current waveforms as shown in Fig. 9(b).



(b)

Case-3: Energizing the capacitor bank producing a sudden change of MVAR as shown in Fig. 9(c).



(c)

Fig. 9 : Compensator performances for different cases.

VI. Conclusion

This research demonstrated that modern transmission static VAR compensator can be effectively applied in power transmission systems to solve the problems of poor dynamic performance and voltage regulation in a 115 KV and 230 KV transmission systems. Transmission SVCs and other FACTS controller will continue to be applied with more frequency as their benefits make the network "flexible" and directed towards an "open access" structure. Since SVC is a proven FACTS controller, it is likely that utilities will continue to use the SVC's ability to resolve voltage regulation and voltage stability problems. In some cases, transmission SVCs also provides an environmentally-friendly alternative to the installation of costly and often unpopular new transmission lines. Dynamic performance and voltage control analysis will continue to be a very important process to identify system problems and demonstrate the effectiveness of possible solutions. Therefore, continual improvements of system modeling and device modeling will further ensure that proposed solutions are received by upper management with firm confidence.

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Anti-Inflammatory and Antioxidant Activities of Zanthoxylum Armatum Stem Bark

By S. C. Sati, M. D. Sati, Rakesh Raturi, P.Badoni, Harpreet Singh

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Abstracts - The present study is an endeavour to evaluate anti inflammatory and antioxidant activities of ehtanolic extract of steam bark of Zanthoxylum armatum. In vivo anti inflammatory activity was evaluated in wistar species of rats by using carrageenin induced paw edema, where as in vitro antioxidant activity was performed by DPPH free radical method. The plant extract exhibited significant anti-inflammatory and antioxidant activities.

Keywords : *Zantoxylum armatum, anti inflammatory, antioxidant, DPPH*

GJRE-J Classification : *FOR Code: 090499*

Strictly as per the compliance and regulations of:

Anti-Inflammatory and Antioxidant Activities of Zanthoxylum Armatum Stem Bark

S. C. Sati[α], M. D. Sati[Ω], Rakesh Raturi[β] , P.Badoni[ψ], Harpreet Singh[¥]

Abstract - The present study is an endeavour to evaluate anti inflammatory and antioxidant activities of ehtanolic extract of steam bark of Zanthoxylum armatum. In vivo anti inflammatory activity was evaluated in wistar species of rats by using carrageenin induced paw edema, where as in vitro antioxidant activity was performed by DPPH free radical method. The plant extract exhibited significant anti-inflammatory and antioxidant activities.

Keywords :Zantoxylum armatum, anti inflammatory, anti-oxidant, DPPH

I. Introduction

Inflammation is considered as a primary physiologic defense mechanism that helps body to protect itself against infection, burn, toxic chemicals, allergens or other noxious stimuli, an uncontrolled and persistent inflammation may act as an etiologic factor for many of these chronic illnesses (Kumar et al., 2004). Although it is a defense mechanism, the complex events and mediators involved in the inflammatory reaction can easily be induced (Sosa et al., 2002). The side effects of the currently available anti-inflammatory drugs pose a major problem during their clinical uses (Mattison et al., 1998). Therefore, the development of newer and more potent anti-inflammatory drugs with lesser side effects is necessary. Reactive oxygen species (ROS) are responsible for variety of pathological conditions (Aruoma, 1998). Innate defense system of human body may not be sufficient for curing the damage caused by continued oxidative stress. Thus there is need to supply the antioxidants exogenously to balance their level in the human body. May synthetic antioxidant, such as butylated hydroxyl toluene (BHT), butylated hydroxyanisole (BHA) antioxidants (Yesilyurt et al., 2008). Therefore recently there has been an upsurge of interest in natural products as antioxidants, as they can inhibit the free radical reaction and protect the human body from various diseases.

Zanthoxylum armatum DC [syn. Z. alatum Roxb.] (Rutaceae) is extensively used in the Indian system of medicines as a carminative , stomachic , and anthelmintic. The bark is pungent , and sticks prepared from it are used for preventing toothache. The fruits and seeds are employed as an aromatic tonic in fever, dyspepsia, and expelling roundworms (Wealth of India, 1976). Phytochemical examinations of Z. armatum have afforded volatile oil consisting mainly linalool (Ramidi, 1998). Mono terpentriol-3, 7-dimethyl 1-octane 3,6,7-triol, trans cinnemic acid, nevadensin umbelliferone, β-sitosterol and its glucoside(Talapatra, et al.,1989), 3,5, dihydroxy-7,8,4'trimethoxyflavone (tamblin) and tambulatin (Nair et al., 1982), 3-methoxy-11-hydroxy-6,8-dimethylcarboxylate biphenyl, 3,5,6,7-tetrahydroxy-3',4'-dimethoxyflavone-5-β-d-xylopyranoside(Akhtar et al., 2009), aramatamide, lignans, asarinin and fragesin, α and β-amyrins lupeol, and β -sitosterol β-Dglycoside(Kalia, et al., 1999) have been reported from the plant previously. Antihelmentic (Mehata et al., 1981), antiprolifative (Kumar et al., 1999], antifungal(Dikshit et al.,1984) and anti-insecticidal activities(Tiwary et al.,2007) have also been studied with different plant parts.

II. Materials and Methods

a) Chemicals

Butylated hydroxyl toluene (BHT), 2, 2 diphenyl-1-picrylhydrazyl and carageenin were purchased from HiMedia Lab. Pvt. Ltd. Mumbai, India. All other chemicals and reagents used were of analytical grade.

b) Animals

Male wistar rats (130-160g) kept the animal house of the IIIM Jammu. The animal were housed under standard environmrntal conditions. All experiment were carried out after getting the approval from the committee for the purpose of control and supervision of experimental animals (CPCSEA) having the registration number is 67/CPCSEA/99.

c) *Effect of Z. armatum extract on carrageenin induced rat paw edema*:

Screening for anti-inflammatory activity of Z. armatum extract was done with a carrageenin induced paw edema model (Winter et al., 1962). Administration of carrageenin in the sub-plantar region of rat's hind paw leads to the formation of edema in situ due to localized inflammation. About half an hour prior to the administration of carrageenin solution, experimental animals received test materials and standard anti-inflammatory drug at appropriate doses. The volume of rat paw was measured each hour up to four hours by means of mercury displacement method in traveling

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microscope assembly (Roy et al., 1980). The average percent increase in paw volume with time was calculated and compared against the control group. Percent inhibition was calculated using the formula

$$\% \text{ inhibition} = \frac{Vc - Vt}{Vc} \times 100$$

Where Vc and Vt represent average paw volume of control and treated animals respectively.

Nine experimental animals were randomly selected and divided into three groups denoted as Group I, Group II and Group III, consisting of 3 rats in each group. Each group received a particular treatment i.e. control, standard drug and the dose of the extract. Prior to any treatment, each rat was weighed properly and the doses of the test samples and control materials were adjusted accordingly. Group I received the crude extract orally at the doses of 250 mg/kg of body weight respectively. Group II received intraperitoneal administration of ibropfen as standard anti-inflammatory drug at a dose of 10mg/kg body weight while Group I was kept as control giving 1% tween 80 in normal saline water. After one hour of drug administration, 0.1 ml of 1% (w/v) carrageenin solution in sterile saline solution was injected through 26-gauge needle into the sub-planter surface of the right hind paw of each rat of every group. Paw volumes were measured up to a fixed mark by mercury displacement as viewed by traveling microscope at 1, 2, 3 and 4 hours after the administration of the standard drug and test extracts.

III. DPPH free Radical Method

In order to measure antioxidant activity DPPH free radical scavenging assay was used. This assay measures the free radical scavenging capacity of the extract under investigation.

DPPH is a molecule containing a stable free radical. In the presence of an antioxidant, which can donate an electron to DPPH, the purple color which is typical for free radical decays and the absorbance was measured at 517nm using a double beam UV-VIS spectrophotometer (Brand et al., 1995). The extract was dissolved in ethanol and various concentrations (10, 20, 50 and 100 µg/ml) of extract were used. The assay mixture contained in total volume of 1 ml, 500µl of extract, 125µl prepared DPPH and 375 µl solvent (ethanol). After 30 min of incubation at 250C, the decrease in absorbance was measured. The radical scavenging activity (RSA) was calculated as a percentage of DPPH using a discoloration using then equation

$$\% \text{ RSA} = [(A0 - As) / A0] \times 100$$

Where A0 and As are the absorbance of control and test sample respectively

IV. Plant Material and Extract

Stem bark of Zanthoxylum armatum were collected from, Singoli Tehri Garhwal Uttarakhand, India and identified from the Plant Identification Laboratory, Department of Botany, H.N.B. Garhwal University Srinagar. A voucher specimen (GUH 3802) was deposited in the Department for future records. The bark was dried under shade and make to powder.

The 2 kg dried powdered bark of plant was exhaustively extracted with ethanol for 72 hour. The solvent were evaporated under reduced pressure in a rotary vacuum evaporator and dried in vacuum. The dried extract obtained was used directly for the assessments of anti inflammatory and antioxidant activities.

V. Results and Discussion

The anti-inflammatory activity of extract Z. armatum was evaluated by carrageenininduced paw edema method in wistar specie of rats. The plant extract at dose 250mg/kg caused inhibition of paw edema by 19.12%, 4 hours after carageenin administration hour (Table I).The 1st, 2nd and 3rd hours results were not significant so we take only 4th hour reading. The carrageenin-induced paw edema in rats is believed to be biphasic (Vinegar et al., 1969). The first phase is due to the release of histamine or serotonin, and the second phase is caused by the release of bradykinin, protease, prostaglandin, and lysosome (Crunkhorn and Meacock, 1971). Therefore, it can be assumed that the inhibitory effect of the extract of plant on carrageenan-induced inflammation could be due to the inhibition of the enzyme cyclooxygenase, leading to the inhibition of prostaglandin synthesis (Biswa Nath Das et al., 2009).

Table 1: Anti-inflammatory activity of Zanthoxylum armatun stems bark

Treatment	Edema volume (ml)* 4th hour	% inhibition
Control	1.26 ± 0.120	
ZA (250/kg)	1.02 ± 0.120	19.02
Ibrofen (5mg/kg)	0.76 ± 0.066	39.68
* value are mean ± SE, n=3, P>0.01, ZA-Z.armatum		

The ethanolic extract of plant showed an effective free radical scavenging in DPPH (2, 2 diphenyl-1-picryl hydrazyl) assay (Table-2). The extract of the plant exhibit a remarkable antioxidant effect at low concentration. When the extract of the plant was tested for DPPH radical scavenging activity, it was found that 50µg/ml and 100µg/ml of the extract lowered the DPPH radical levels above 57% and 94% respectively. Inhabitation of DPPH radicals 50% considered as significant antioxidant properties of any compound (Sanchez-Moreno et al., 1998).

Table 2 : Antioxidant activity of Zanthoxylum armatum stem bark

Concentration ε (g/ml)	DPPH Free radical Scavenging
50	7.06
100	14.22
200	27.33
500	64.58

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Prospects of Renewable Energy and Energy Storage Systems in Bangladesh and Developing Economics

By Md M. Biswas, Kamol K. Das, Ifat A. Baqee, Mohammad A. H. Sadi, Hossain M. S. Farhad

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Abstracts - Bangladesh is facing daunting energy challenges that are merely likely to deteriorate over the next few years. Further, over fifty percent of Bangladesh's inhabitants live without electricity, and the grid expansion rate to connect rural areas is threatened by the looming capacity shortage. By acknowledging the potential of renewable energy technologies (RETs) and associated energy storage, Bangladesh could possibly meet its unprecedented energy demand, thus increasing electricity accessibility for all and as well as financial growth. This paper represents a baseline overview of prospects of renewable energy recourses, and a survey on energy storage systems related to RETs, and estimates the potential for commercial applications of these resources now and in the future All the latest information regarding renewable energy and associated energy storage systems have been collected from different government and private sectors including NGOs which are working with solar home systems (SHSs), wind power generation, biomass and biogas energy, hydro energy and battery as energy storage. The paper concludes that the RETs create income-generating activities for village people while reducing environmental problems, like deforestation and indoor air pollution from cooking with poor quality fuels.

Keywords : *Bangladesh, power generation, renewable energy, solar home systems (SHSs), energy storage system, economic development.*

GJRE-J Classification : *FOR Code: 091499*

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Prospects of Renewable Energy and Energy Storage Systems in Bangladesh and Developing Economics

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Abstract - Bangladesh is facing daunting energy challenges that are merely likely to deteriorate over the next few years. Further, over fifty percent of Bangladesh's inhabitants live without electricity, and the grid expansion rate to connect rural areas is threatened by the looming capacity shortage. By acknowledging the potential of renewable energy technologies (RETs) and associated energy storage, Bangladesh could possibly meet its unprecedented energy demand, thus increasing electricity accessibility for all and as well as financial growth. This paper represents a baseline overview of prospects of renewable energy recourses, and a survey on energy storage systems related to RETs, and estimates the potential for commercial applications of these resources now and in the future All the latest information regarding renewable energy and associated energy storage systems have been collected from different government and private sectors including NGOs which are working with solar home systems (SHSs), wind power generation, biomass and biogas energy, hydro energy and battery as energy storage. The paper concludes that the RETs create income-generating activities for village people while reducing environmental problems, like deforestation and indoor air pollution from cooking with poor quality fuels.

Keywords : *Bangladesh, power generation, renewable energy, solar home systems (SHSs), energy storage system, economic development.*

I. Introduction

Bangladesh is situated in north-eastern part of south Asia and shares its longest border (4000 km) with neighbouring country India. Myanmar is the extreme southeast neighbour of Bangladesh and the Bay of Bengal is the southern boundary of it. With a land area of 147,570 km^2 and population of 162.20 million in 2011, Bangladesh is among the world's most densely populated nations (1099 people/km^2 in 2010) [1]. Bangladesh is one of the least urbanized nations with 72% people living in rural areas. Again, it is one of the poorest nations in the whole world with gross domestic Product (GDP) per capita of US $1,700 in 2010 and average annual growth of GDP is to be 6% [2].

Energy, and more explicitly electricity, is a pre-requisite for the technological development, higher economic growth and poverty reduction of a nation. The future economic development of Bangladesh is likely to result in a rapid growth in the demand for energy with accompanying shortages and problems. The country has been facing a severe power crisis for about a decade [3]. Known reserves (e.g., natural gas and coal) of commercial primary energy sources in Bangladesh are limited in comparison to the development requirements of the nation.

By acknowledging the potential of renewable energy resources, Bangladesh could possibly meet its unprecedented energy demand, thus enhancing electricity accessibility to all and increasing energy security through their progression. The country has modest hydrocarbon resources and rich renewable energy sources particularly in the form of traditional energy resources [1]. Appropriate integration of renewable energy technologies (RETs) in the power sector through national energy planning would be, therefore, the right direction, not only for sustainable development of the country but also as the responsibility of Bangladesh toward the global common task of environmental protection from pollution [3]. RETs have become multi-billion dollar industry from the realm of laboratories in recent years. At present, most of the large international oil companies have started serious business with renewable energies [4].

Renewable energy technologies (RETs) offer developing countries like Bangladesh some prospect of self-reliant energy supplies at national and domestic levels, with potential economic, social, ecological, and security benefits. Some RET models have already been implemented in rural areas in Bangladesh. However, these models do not specifically allow the poorest peasant control over RETs and the income generated by them. The major sources of renewable energy in Bangladesh include solar, wind energy, biomass and biogas, and hydro [5]. Other minor renewable energy sources are bio-fuels, gasohol, geothermal, river current, wave and tidal energy. Potentialities of these minor sources are yet to be explored.

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The existing circumstances in the electricity market in Bangladesh may offer unique opportunities for energy storage technologies, predominantly in combination with renewable energy generation, in which a few seconds to a few hours of electricity can be stored for use at a later time [6]. These systems can be positioned near the generator, transmission line, distribution substation, or the consumer's premise, depending on the application they are addressing. Storage can play a flexible, multi-function role in the electricity supply system to manage resources efficiently. Electric energy storage promises other benefits unrelated to renewable energy, such as superior grid reliability and stability, deferral of new generation and transmission investments, and other grid benefits [7]. In combination with renewable energy resources, energy storage systems (ESS) can increase the value of photovoltaic (PV) and wind generated electricity, by making supply coincident with periods of peak consumer demand [8].

This paper is organized as follows: First, a brief overview of current power situation in Bangladesh is presented in Section II to initiate the required impression throughout this paper. This is followed by a review of leading renewable energy resources available in Bangladesh in Section III, which have already found potential applications in different sectors. Section IV covers a brief surveillance on upcoming renewable energy based power generation projects. Energy storage system contributing renewable energy sectors such as battery is reviewed in Section V. Finally, in Section VI, possible economic developments using the RETs for rural people are discussed elaborately, which is followed by concluding remarks in Section VII.

II. Present Power Scenario in Bangladesh

Bangladesh is experiencing intimidating energy challenges: Security concerns over growing fuel imports, limited domestic energy resources for power generation. At present the power demand in Bangladesh is about 6000MW, whereas the generation ranges only 4000-4600 MW. The generation capacity is 5936MW [9]. As a result of power shortage causes excessive load shading throughout the whole year. Bangladesh relies greatly on fossil fuels for its energy, but the present reserve would be depleted by the year of 2015 [10]. Here, coal is still the major fuel for power generation. Bangladesh has adequate high quality coal resources. But the coal mining has not been started effectively. Exploration and development of natural gas resource has almost reduced to zero. Also the exploration of coal continues to remain uncertain. Consequently, the shortage of power can be met by renewable energy resources which are abundant in nature.

Table I : Present Power Scenario in Bangladesh

Sl. No.	Items	Status (2011) [9]
1	Electricity Growth	10 % in FY-2010 (Av. 7 % since 1990)
2	Total Consumer	12 Million
3	Transmission Line	8,500 km
4	Distribution Line	2,70,000
5	Distribution Loss	13.1%
6	Per Capita Generation	236 kWh (incl. Captive)
7	Access to Electricity	48.5 %
8	Present Generation Capacity	5936MW
9	Present Demand	6000MW
10	Present Available Generation	4000 – 4600 MW
11	Recent Maximum Generation s	4699 MW (20 August 2010)
12	Maximum Load Shedding in FY-10	1500 MW (during hot summer days)

III. Leading Renewable Energy Resources in Bangladesh

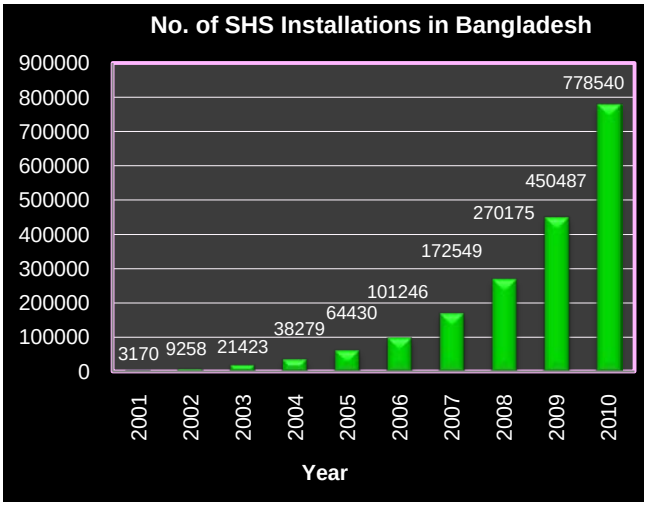
Renewables are an almost unlimited source of energy if one considers the energy necessary by mankind, compared with the huge amount of energy we receive from the sun. Gradually renewable energy and its different energy conversion technologies have become economically viable, capable of competing with fossil-fuelled technologies in the energy market. The size and economic potential of the renewable energy resources (e.g., solar energy, wind power, biomass and biogas etc.) in Bangladesh are yet to be determined and the capacity of renewable energy development is presently low. Although investment costs of renewables are generally higher compared to fossil fuel alternatives, this option becomes economically viable when all externalities (e.g. environmental cost, health hazards etc.) and lower operating cost are taken into consideration [11].

a) Solar Energy

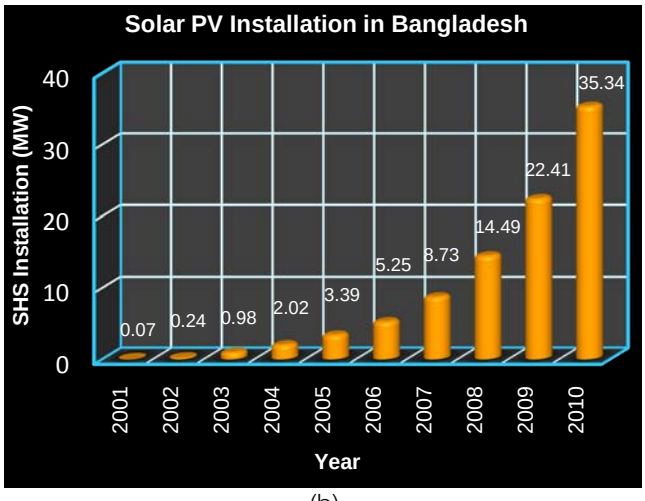
The energy from sunlight reaching the earth is a huge potential that can be exploited and used for generating electricity. Among a number of available technologies, solar photovoltaic (PV) is the most promising. PV technology converts sunlight into direct current (DC) electricity. When light falls on the active surface of the solar cell, electrons become energized and a potential difference is established, which drives a current through an external load. The central issue for the PV technology is cost. The unit cost of PV has sunk in several orders of magnitude while the efficiency is continuously being improved. Solar PV is becoming more and more popular due to high modularity, no

requirement for additional resource (e.g., water and fuel), no moving parts, and low maintenance needed. Over the last two decades, the cost of manufacturing and installing solar PV system has decreased by about 20 % for every doubling of installed capacity [12]. In the whole world solar power generating capacity grew by 70 % in 2008 and 47% in 2009, but still fast enough to leave global solar capacity at the end of 2009 more than twice as high as it was at the end of 2007. The solar industry has grown at a rate of 35 % per year over the last ten years [13].

Fig. 1: Installing a solar PV system in a rural area.



(a)



(b)

Fig. 2 : SHS Installation in Bangladesh [16]: (a) number and (b) equivalent power.

Bangladesh is located between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Here, the daily average solar radiation varies between 4 to 6.5 kWh per square meter [4]. Maximum amount of radiation is available on the month of March-April and minimum on December-January.

Infrastructure development company limited (IDCOL) has supported NGOs in installation of solar home systems (SHSs) and a total of 801,358 SHSs having capacity of about 36.5 MW have been installed upto January 2011 [14]. Fig. 1 shows the installation of a solar PV system on the roof of a village house in Bangladesh. The number of SHS installed in Bangladesh is shown in Fig. 2 (a) and the equivalent power in Fig. 2 (b). It demonstrates that the rate of SHS installation is increasing significantly per year.

Bangladesh power development board (BPDB) has implemented an excellent Solar PV electrification project in the Chittagong hill tracts region. The Solar PV electrification has emerged as the most appropriate technological option for the electrification of these areas [15]. A 10 kW central AC solar PV system has been installed in one selected market in each of the three Rangamati district's sub-districts (Fig. 3). With these systems, the shops of that market have been electrified with normal AC electricity.

b) Wind Energy

The energy from continuously blowing wind can be captured using wind turbines that convert kinetic energy from wind into mechanical energy and then into electrical energy. Electricity generated by wind turbines can feed to the central grid or be locally consumed using small stand-alone wind turbines. Gradually

Fig. 3 : Solar Arrays of 10 kW centralized AC market electrification systems at Barkal, Rangamati.

Fig. 4 : Wind turbines of 1000 kW capacity WBHPP at Kutubdia Island, Cox's Bazar district (Bay of Bengal).

Generation of electricity from wind energy becomes very much promising where speed and wind power density is sufficiently high [3]. Wind power generating capacity growth accelerated to 31% in 2009 through the whole world, with capacity increasing by a record 38 GW to reach 160 GW by the end of 2009. This was the sixth consecutive year of accelerating growth, a remarkable achievement in a year of global economic recession. Wind turbines for grid-connected systems are the most highly demanded on the market and the rate of capacity growth is 28% per year between 1999 and 2009 [17].

In Bangladesh, especially at coastal areas there are some islands and inlands where wind energy can play a very important role to progress the economy of the country. BPDB installed a 160 feet tower at the Muhuri Dam site in the Feni district in May 2003. Two high resolution anemometers were installed on this tower, one anemometer at 80 feet and the other at 160 feet height. One wind vane has been installed at 80 feet height. The average wind speed, till to date, at the Muhuri Dam areas is found to be as 6.50 m/s and the wind power density varies from 100 to 250 Watt/m^2 in the coastal regions of Bangladesh [18]. For the financial viability of the grid connected wind turbines, the required annual average wind speed is 6 m/s. So, the wind speeds are encouraging for the grid connected wind energy projects in the areas of the Muhuri Dam, Feni [19]. This site is large enough for the larger wind energy projects.

BPDB implemented a 1000 kW capacity wind battery hybrid power project (WBHPP) at the Kutubdia Island (Bay of Bengal) in the Cox's Bazar district (Fig. 4). Under this project, total 50 nos. of 20kW capacity stand alone type wind turbines are being installed. The total capacity of all the wind turbines is 1 MW. The wind turbines producing electricity is being stored in battery bank. WBHPP was officially started on March 30, 2008. In another project, BPDB has implemented a 0.90 MW capacity of the grid connected wind energy (GCWE) at the Muhuri Dam areas in the Feni district in 2004. The installation, commissioning and erection works of 4 units of the 225 kW GCWE turbines at this site had been completed in 2004. This is the first ever GCWE project in Bangladesh. Thus generating electricity from wind in the coastal areas can be transmitted to other regions of the country through the high voltage transmission lines [19]. Very little operation and maintenance will be required during the whole life time of wind turbines and no fuel will be required for generating electricity from wind.

c) Biomass and Biogas

Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries. Biomass covers all kinds of organic matter from fuel wood to marine vegetation. Energy generation using biomass offers a promising solution to environmental problems by reducing the emission of common greenhouse gases. There have several technologies for conversion of biomass into energy such as heat energy and electrical energy. Two widespread technologies are direct combustion and gasification. Direct combustion involves the oxidation of biomass with excess air, producing hot flue gases which in turn produce steam, which is used to generate electricity [20]. Gasification involves conversion of biomass to produce a medium or low calorific gas. The gained gas is then used as fuel in combined cycle power generation plants. Being produced in combined cycle power plants, electricity from this technology has higher efficiency and is more competitive than that from a steam turbine. Electrical conversion efficiencies up to 40% are possible on a scale of about 30 MW on the short term [21]. Anaerobic digestion of biomass has been demonstrated and applied commercially for a variety of feedstock, such as organic domestic waste, organic industrial waste, manure, sludge, etc.

Biogas is a mixture of CH_4 (40 – 70 %), CO_2 (30 – 60 %) and other gases (1 – 5 %) produced from animal dung, poultry droppings, and other biomass wastes in specialized bio-digesters. This gas is combustible and can be used to generate electricity [22]. Biogas can be applied for cooking and power generation. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources of Bangladesh. It is a potential source to harness basic biogas technology for cooking and rural and peri-urban electrification to provide electricity during periods of power shortfalls.

Biomass is the most significant energy source in Bangladesh which accounts for 70% of the total final energy consumption [4]. This technology can be disseminated on a larger scale for electricity generation. IDCOL financed a 250 kW Biomass based power plant at Kapasia, Gazipur. The plant uses locally available agricultural residues i.e. rice husk as fuel for power generation. Being located in an unelectrified area, the plant is expected to supply environment friendly grid

Fig. 5 : Construction of a biogas plant in a rural area of Bangladesh.

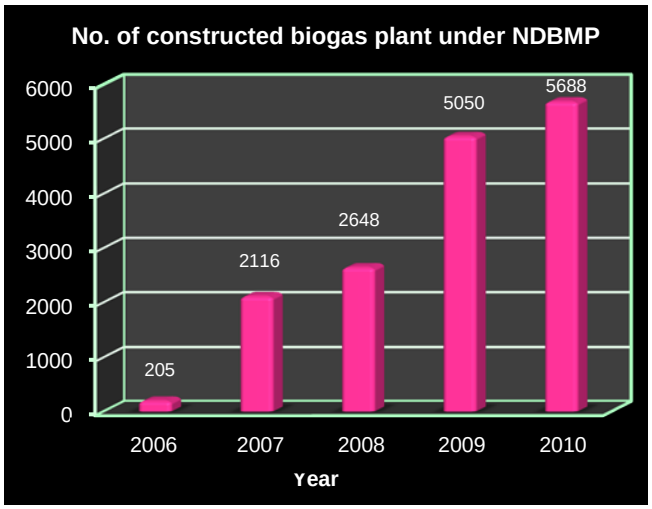


Fig. 6 : Biogas plants construction in Bangladesh under NDBMP [25]-[26].

quality power to 300 households and commercial entities of that area [23].

There are three million potential household with adequate cattle or poultry. In Bangladesh biogas is being used mainly for cooking purpose. From 1971 to October 2009 About 41000 biogas plants has been constructed by different NGOs, under national domestic biogas and manure programme (NDBMP) of IDCOL, sustainable energy for development (SED) program of German technical cooperation (GTZ), and other government organizations e.g. local government engineering department (LGED), Bangladesh council of scientific and industrial research (BCSIR) [24]. Under NDBMP of IDCOL, 5688 biogas plants have been constructed in Bangladesh in the year of 2010 (Fig. 6).

d) Hydro Energy

Kinetic energy from flowing or falling water is exploited in hydropower plants to generate electricity. Hydropower plants are classified into two categories: 1) Large hydropower plants (>10 MW), usually with reservoirs, that cannot only produce electrical energy Continuously, but also are able to adjust their output according to electricity demand and 2) small hydropower plants (<10 MW) that are less flexible with respect to load or demand fluctuation due to their dependence on the water resource [3]. Hydropower technologies are mature and widely available.

In Bangladesh about 1.4 trillion cubic meters (m^3) of water flows through the country in an average water year. Major rivers of the country have a high rate of water flow of about 5 to 6 months during monsoon season, which is substantially reduced in winter season. More than 90% of Bangladesh's rivers originate outside the country, due to which proper planning of water resource is difficult without neighboring countries cooperation. Downstream water sharing with India is a highly contentious issue for Bangladesh. The annual average rainfall is about 2,300 mm, which varies from 1,200 mm in the north-west to 5,800 mm in the north-east. Most of the rainfall (about 80%) occurs during the months of May/June to September/October [4]. At present only 230 MW of hydro power is utilized in Karnaphuli, Rangamati hydro station, which the only hydro-electric power plant operated by BPDB [27]. Microhydro and minihydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed [5].

IV. Renewable Energy Based Power Pants: Future Plan

Development of renewable energy in Bangladesh is insufficient. Besides the conventional energy, in order to promote the renewable energy the activities of sustainable energy development authority (SEDA) have been accelerated in Bangladesh. As per approved renewable energy policy 5% of the total generation (450 MW) would be added by 2015 and 10% of the total generation (1600 MW) would be added by 2020 from renewable sources [28].

With an average annual direct normal irradiance (DNI) of 2,000kWh/m^2, the area required to generate 100MW of electricity is about 2km^2. Bangladesh receives an average annual DNI of nearly 1,900kWh/m^2 which is adequate to operate a concentrating solar power (CSP) plant [29]. On March 14, 2011, Bangladesh has set a target to produce 500 MW of electricity installing solar home systems to reduce greenhouse emissions and ensure sustainable development in energy sector [30]. It also plans to install solar irrigation system to cut diesel cost.

BPDB established a wind resource assessment station (WRAS) at the Moghnama Ghat, Cox's Bazar. The installation, commissioning, erection, testing etc. works of this WRAS have been completed in December 2003. So far wind resource data of this site have been

gathered and these data shows the clear viability of grid connected wind energy at this site [19]. Another WRAS installation at Kuakhata, Patuakhali is under process to measure the wind potential at that location.

In Bangladesh, about 8-9 million metric tons of rice husk is produced annually. So, theoretically there is a potentiality to generate 400 MW biomass gasification based electricity. Again, there are three millions of potential households with adequate cattle or poultry and it reveals the potentiality of 800MW biogas based electricity plant [24]. BPDB is considering extension of Karnaphuli hydro station to add an additional 100 MW electricity, which will be effective to operate it as a peaking power plant [4]. The additional energy will be generated during the rainy season when most of the year water is spilled.

V. Energy Storage in Renewable Energy Sectors

Energy storage improves the efficiency and reliability of the electric supply system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient base load generation, and allowing greater use of intermittent renewable energy technologies. Energy storage can help to increase energy security, reduce the environmental impact of electricity generation, transmission and use, and broaden the diversification opportunities for utilities by adding more generation options to their portfolios [21]. Energy storage technologies include batteries, flywheels, ultracapacitors and superconducting magnetic energy storage (SMES) for short term storage and pumped hydropower, compressed air energy storage for long term storage [32].

Table II : Renewable Energy Projects [9], [23], [31]

Sl No.	Location of the Project	Capacity (MW)	Type of Project
1	Parki Beach, Chittagong	100-200	Wind Power
2	Moghnamogha, Cox's Bazar	10	Wind Power
3	Hatia, Sandwip, and Monpura Islands	4	Wind Power
4	Bazitpur, Kishoreganj	18	Grid Connected Solar PV
5	Kaptai, Rangamati	5	Grid Connected Solar PV
6	Sarishabari, Jamalpur	2-4	Grid Connected Solar PV
7	RTC, Rajshahi	1	Grid Connected Solar PV
8	Rajabarihat, Rajshahi	2-4	Grid Connected Solar PV
9	St. Martin Island	1.5	Wind and Solar Hybrid
10	Chilarong, Thakurgaon	0.4	Biomass

Lead-acid batteries are mainly used as energy storage systems in the renewable energy sectors in Bangladesh. Here, two types of industrial batteries are produced: tubular plate batteries, and flat type batteries. Because of the higher durability, consumption of tubular plate battery is higher than the flat type. Most of the tubular plate battery is now locally manufactured with a total capacity of 201,000 per year [16]. Major manufacturers include Rahimafrooz, Rimso, Hamko, Navana, Pannaand, and few others (Fig. 7). In terms of cost, 70% of the raw materials are imported and the major raw materials include lead, separators, casing etc.

Rahimafrooz batteries limited (RBL) is the largest lead-acid battery manufacturer in Bangladesh and offers an extensive range of automotive and specialised industrial battery. The company manufactures over 300 different types of automotive and industrial batteries. It has technical collaboration

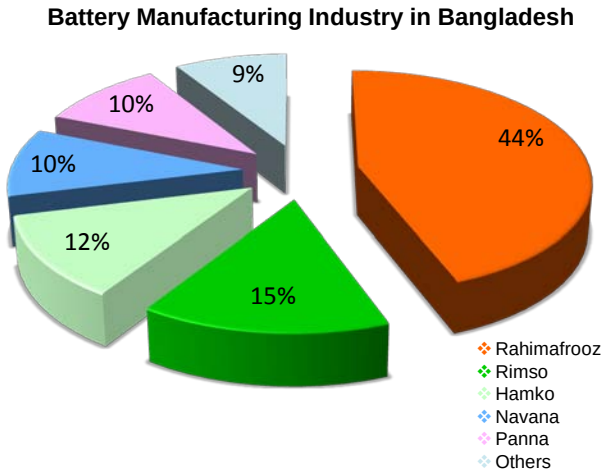


Fig. 7: Tubular battery manufacturers in Bangladesh[16].

Fig. 8: Battery bank of 1000 kW capacity WBHPP at Kutubdia Island, Cox's Bazar.

Agreements with UK-based Lucas Battery Company, technical support group, Hawker batteries, Invensys and Hawker batteries, Eltek of Norway, and AEES of France, to ensure the quality of the battery [33].

The wind turbines using at Kutubdia Island, Cox's Bazar produce electricity and charges the batteries at battery banks as shown in Fig. 8, which consisting of 1000 numbers of 200AH with capacity of 12VDC [34]. The stored electrical power from the battery banks is converted to AC by using inverters and distributed to the consumers through overhead power cable.

VI. Economic Development Through Renewable Energy

Access to energy has become essential to the functioning of modern economics. To alleviate poverty in the face of resource limitations and high population density, Bangladesh requires an economic growth rate of more than 7%. In order to achieve this growth rate electricity growth need to be achieved by 10%. Commercial energy in Bangladesh is dominated by natural gas, particularly in power generation. This is supplemented by imported liquid fuel; indigenous coal is yet to make any significant impact in the energy scenario. While sustained energy supply is a prerequisite for economic development, current information indicates that the existing gas reserves will be able to meet the gas demand (at 7% per annum) up to 2016 though with the present production capacity it cannot meet the existing demand [28].

In Bangladesh the natural trend towards teledensity is growing. Moreover, the government is trying to implement a digital superhighway facility for the nation. Consequently, the need for communication equipment is of the first priority. It is therefore essential for the telecommunication operators to ensure a continuous power supply economically at the time of crisis. Solar energy can be the most suitable solution for alternate more reliable sources of energy. This will improve the the coastal region wind solar hybrid system Can ensure service of the telecom companies, and also allow them to cover off grid areas and thus contributing the rural inhabitants' financial development. Renewable energy technologies (RETs) could be selectively applied to various rural applications, potentially generating income, improving health and educational quality, and increasing labour productivity. However, such potential benefits arising from RETs may be realized only through a process that appropriately harnesses the social and financial context of village life. There are practical implementations of RETs in other rural situations that have succeeded in catalysing endogenous development, including job creation. Fig. 9 represents a model for addressing benefits of sustainable development of the rural poor using RETs.

VII. Conclusion

The summery demonstrates that there is considerable opportunity for Bangladesh to meet its future power demand and thus economic growing through renewable energy. Bangladesh already has experienced with sustainable energy projects and certain renewable energy project approaches. Though these initiatives are at initial stage of development and implementation, the potential of these initiatives is high. There are many possible ways in which these goals can be carried out in Bangladesh; through combinations of different renewables technologies, grid based generation and micro-renewables, and energy efficiency. In Bangladesh, diffusion of renewable energy technologies has gained momentum in recent years via evolution of relevant policies, institutional facilitation and learning-by-doing experience. Renewable energy policy has been adopted by the government of Bangladesh on December 18, 2008. Sustainable energy development agency (SEDA) will coordinate activities related to the development of renewable energy technologies and financing mechanisms in the country.

Bangladesh has got ample solar insolation throughout the country. Daily average solar radiation varies from 4 to 6.5 kWh/m^2. There is intense prospect of

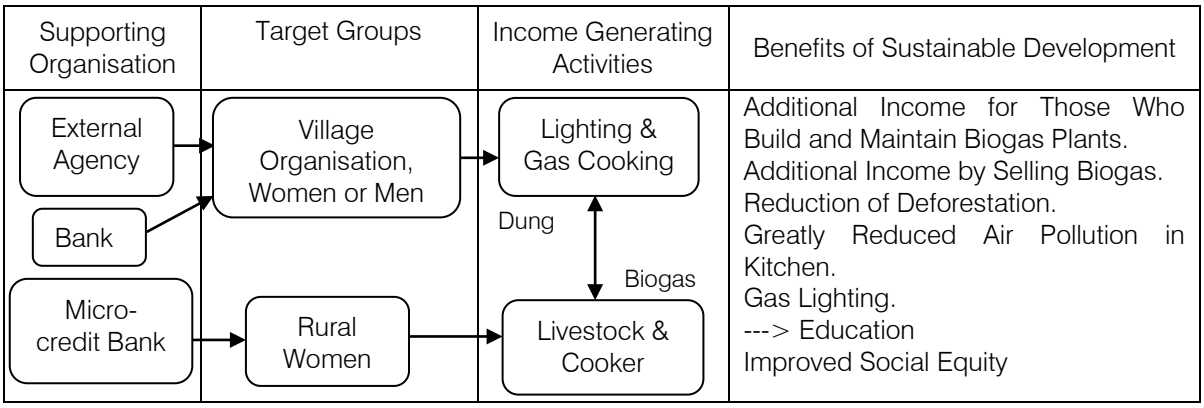


Fig. 9 : Simplified system using biogas.

Solar photovoltaic and solar thermal systems in the rural as well as urban areas of the country. BPDB's established WRAS is expected to provide more valuable information regarding wind energy potential for larger projects in Bangladesh. Bangladesh consists of diverse potentials of biomass and biogas energy. Many waste-to-energy projects have proven budding applications of biomass and biogas which will not only provide electricity, but also reduce the unpleasant waste disposal problems of metropolitan cities of the country. There is limited potential of small hydro power plants in country. BPDB and Bangladesh water development board (BWDB) are presently working together to implement a pilot project at any of the prospective regulating structures of Tista Canal system.

Among the different energy storage technologies only batteries have found potential application in renewable energy sectors in Bangladesh and it shows a bright prospect in storage of electricity generated by renewables. This survey has been accomplished by the information available at the present time and more detailed statistics on energy use in Bangladesh. Finally a model has been developed in which it is shown that RETs, using appropriately, may improve the quality of life of rural people and provide income-generating opportunities with redressing social inequities and environmental impacts in Bangladesh.

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Effective Power System Stabilization Using Non-Dominated Ranked Genetic Algorithm

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Abstracts - Power system stabilizers (PSS) should be accomplished with suitable stabilization signals over a wide range of operating environment and disturbances. With the enormous electric power need and requirement to function the power system in a faster and highly flexible way in the deregulated competitive situation, modern power systems can achieve stressed conditions very easily than the old systems. These make unbalanced or badly damped oscillations that have been seen more frequently in power systems across the world. In modern days, stabilizing control techniques for the multi-machine power system with the help of intelligent methods have been developed. The basis for the reduction of stability analysis is because of the complexity of the power systems. In addition, industry will be unwilling to acknowledge controller design if stability is not be assured. To deal with those problems, intelligent techniques are used. The optimal sequential design for multi-machine power systems is very essential. As a result, serious consideration is now being given on the concern of power system stabilization control. In recent times, the utilization of optimization techniques becomes possible to deal with control signals in power system. Most widely used optimization technique is Genetic Algorithm (GA). However, GA takes more time in optimization and lack in accuracy. To overcome those difficulties, this paper uses Non-Dominated Ranked Genetic Algorithm (NRGA) for optimization. Simulation results suggest that the proposed technique is better for power system stabilization when compared to the conventional techniques.

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Effective Power System Stabilization Using Non-Dominated Ranked Genetic Algorithm

V.Ravi[α], Dr. K.Duraiswamy[Ω]

Abstract - Power system stabilizers (PSS) should be accomplished with suitable stabilization signals over a wide range of operating environment and disturbances. With the enormous electric power need and requirement to function the power system in a faster and highly flexible way in the deregulated competitive situation, modern power systems can achieve stressed conditions very easily than the old systems. These make unbalanced or badly damped oscillations that have been seen more frequently in power systems across the world. In modern days, stabilizing control techniques for the multi-machine power system with the help of intelligent methods have been developed. The basis for the reduction of stability analysis is because of the complexity of the power systems. In addition, industry will be unwilling to acknowledge controller design if stability is not be assured. To deal with those problems, intelligent techniques are used. The optimal sequential design for multi-machine power systems is very essential. As a result, serious consideration is now being given on the concern of power system stabilization control. In recent times, the utilization of optimization techniques becomes possible to deal with control signals in power system. Most widely used optimization technique is Genetic Algorithm (GA). However, GA takes more time in optimization and lack in accuracy. To overcome those difficulties, this paper uses Non-Dominated Ranked Genetic Algorithm (NRGA) for optimization. Simulation results suggest that the proposed technique is better for power system stabilization when compared to the conventional techniques.

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I. Introduction

Highly complicated power systems have been constructed to deal with the increasing demand. The development in electric power production is focused on the interconnected network of transmission lines linking generators and loads into huge integrated systems which helps in better supply of power. This huge venture of providing electrical energy suffers various engineering difficulties that afford the engineer with a range of challenges. The systems that are developed according to this are highly complicated in its planning, construction, and operation. The stabilization of the power systems is the foremost issue that should be taken into account.

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The field of power system dynamic stability has become a wide area of research due to large scale interconnection of the power system. This research area involving the power system stability has been gaining more and more importance since 1920 because of the problems occurring due to the instability in the power systems. Moreover, requirement for consumption of energy has been amplified extensively because of the industrial revolution. The stability issue in a power system is considered as one of the most important and essential concepts of power systems quality.

Dynamic stability is a phenomenon that deal with the approach the system adapts with a novel state following a disturbance [4]. These disturbances are mainly caused due to switching-off a load or a change in the mechanical input to the system. These variations cause oscillations in the system which could ultimately become larger and makes the synchronous generators to go out of step and lose synchronism. The application of fast static excitation system, while offering a gain in stability limits, can lead to poor system damping under certain loading conditions [5].

Power system stabilizers (PSS) [17-19] have been used for a long time to enhance the power system damping. Traditionally, lead-lag structures have been used as power system stabilizers. Much has been published on the ways to tune the parameters of the lead lag controller. These controllers have previously been tuned for both single and multiple operating points of the power system [5]. The methods used for tuning range from pole placement, to the more recent one using the heuristic optimization algorithms like the genetic algorithms [5] and particle swarm optimization [2].

The highly complex, dynamic behavior and nonlinearity of power systems, together with their almost continuously time varying nature, have posed a great challenge to power system control engineers for decades. A crucial issue encountered at the generating plant level is to maintain stability or synchronism of synchronous generators when subjected to severe disturbances at various operating conditions. An effective and economical means to enhance the power system stabilization is a major concern in the present scenario. Generally, the dynamic interaction effects among various modes of the machines are found to

have significant influence on the stabilizer to one machine at a time may not finally lead to an overall optimal choice of PSS parameters. Moreover, the stabilizers designed to damp one mode can create adverse effects in other modes. The optimal sequential design for multi-machine power systems available in the literature suffer from several drawbacks. This section provides better technique for stabilizing the power system. Genetic Algorithm techniques have been used to enhance the stabilization of the power systems [15, 16].

Genetic Algorithms (GAs) are global optimization techniques that utilize concurrent search from multiple-points rather than from a single-point. GA is independent of the problem complexity. The main necessity of the GA is to specify the objective function and to place finite bounds on the parameters. GA is widely used for robust Power System Stabilization [5-9]. Various approaches like self-adaptive GA operators [10-12] and parallel GAs [13-14] are present in the literature to enhance the GA performance in searching for the global optimum. Significant performance can be obtained by these techniques. But, if the searched global optimum is being existed outside the proposed search space of the problem, these techniques cannot allow Genetic Algorithm to find this optimum.

Generally, the application of GA in large scale and complex projects needs high computational effort to estimate individuals and this makes it difficult to maintain large populations. Various approaches have been proposed to calculated fitness of individuals instead of evaluating them directly [7]. It can be assumed that individuals are somehow genetically related with each other. In such case, large population size can be handled by clustering the population into groups of similar individuals [5].

Optimization using GA techniques [23] are widely applied in many real world problems such as image processing, pattern recognition, classifiers, machine learning. There are various forms of GA for different purposes. This proposed approach uses Non-Dominated Ranked Genetic Algorithm for the stabilization of power systems.

II. Literature Survey

Several researches have been done in the field of power system to provide stability. Various techniques are proposed by several researchers which have its advantages and disadvantages. Some of the techniques are discussed below.

Shahab *et al.,* [1] proposed power system stabilization using adaptive neural network-based dynamic surface control. The power system with an excitation controller is denoted as a class of large-scale, uncertain, interconnected nonlinear continuous-time system in strict-feedback form. Consequently, Dynamic Surface Control (DSC)-based adaptive Neural Network (NN) controller is intended to solve the repeated differentiation of the control input that is observed in the traditional back-stepping technique. The approximation of the unknown subsystem and the interconnection dynamics is used by the neural networks. With the help of the new online NN weight update laws with quadratic error terms, the closed-loop signals are found to be locally asymptotically stable via Lyapunov stability analysis, even in the presence of neural network approximation errors. This is in contrast with other neural network approaches where a bounded stability is normally assured. The performance efficiency of the proposed approach in damping oscillations that occur after disturbances is obtained by the simulation results on the IEEE 14-bus power system with generator excitation control. The result is a nonlinear decentralized adaptive state-feedback excitation controller for damping power systems oscillations in the presence of uncertain interconnection terms.

A robust decentralized controller based on optimal sequential design is proposed by Yoshitaka *et al.,* [2]. The inter-area oscillation mode on design phase can be directly considered by the proposed controller. Moreover, the sequential process is applied to design for robust controllers. The best design sequence of the controller is determined by using the condition number. The performance of the proposed controller is illustrated by comparing it with traditional controllers. Damping of many oscillations for a multi-machine power system is illustrated via simulations, which regard as a three line-to-ground fault for power system disturbance [20,21].

Dynamic stability problems are usually overcome through the application of Power System Stabilizers. Vournas *et al.,* [3] proposed presented an alternative technique for power system stabilization [25] based upon the tuning of the existing generator controllers, both governors and A.V.R.'s. The sensitivities of the eigenvalues to the controller parameters are estimated and an optimization approach is designed to maximize the dynamic stability. A significant approach to stabilize a number of unstable oscillatory modes by relatively small parameter variations is by the application of the parameter optimization technique on a realistic model of the Hellenic Interconnected System. The results are tested with a nonlinear simulation program and the stabilization obtained as given by the rotor angle swings is very efficient.

The acceptance of fuzzy logic within the power industry has seen very a few successes because of the requirement for prior information about an extremely complex system. Soon *et al.,* [4] proposed a Fuzzy Logic Controller (FLC) for decentralized stabilization of multi-machine power systems. The authors presented a unique, largely analytical technique for design of robust Multi-Input–Single-Output (MISO) FLC for enhancing damping and stability of an electrical power system without affecting the voltage regulation. The proposed

decentralized FLC uses a systematic analytical approach based on a performance index in order to bypass the need for prior knowledge about the system. The proposed FLC tracks speed deviations to zero in order to stabilize the power output of the generator, while, at the same time, it controls and stabilizes the terminal voltage of the generator. FLC successfully stabilizes both voltage and power oscillations following small and large disturbances in a power system. A multi-machine power system, which includes a four-machine and a ten-machine (New England) system is used for the simulation of the FLC technique. The simulation results clearly showed the effectiveness of designed FLCs in stabilizing the system. The result of the FLC technique is compared with the classical Power System Stabilizers (PSSs) [22, 24] tuned by a conventional linear sequential tuning method (LSM) and optimization-based method.

Yagami *et al.,* [5] provides a power system stability improvement technique with the help of grouping of fault current limiter and thyristor controlled braking resistor. The fault current limiter functions for restriction of fault currents, improvement of the power system stability and containment of turbine shaft torsional oscillations. Next, the thyristor controlled braking resistor functions with the intention of quick managing of generator disturbances. The success of both devices has been illustrated with the help of 3LG (three-lines-to-ground) fault in a two-machine infinite bus system. Simulation results represent a better power system stability improvement and also the damping turbine shaft torsional oscillations with permitted level of temperature rise.

III. Methodology

The power system dynamic stability characteristic acts as a forever growing field of research because of the large scale interconnection of the power system. This field has been recognized as a significant problem for secure system operation from the 1920's [27]. There were various most important collapses resulted by the instability of a power system that indicates the significance of this trend [26]. The stability maintenance in a power system is considered as one of the highly important and necessary factor of power systems quality.

a) Power System Modeling

The model of multi-machine power system considered for this proposed approach is shown in figure 1. The multi-machine consists of 3 machine nine bus system. G_1, G_2 and G_3 are machine present in the multi-machine taken into consideration.

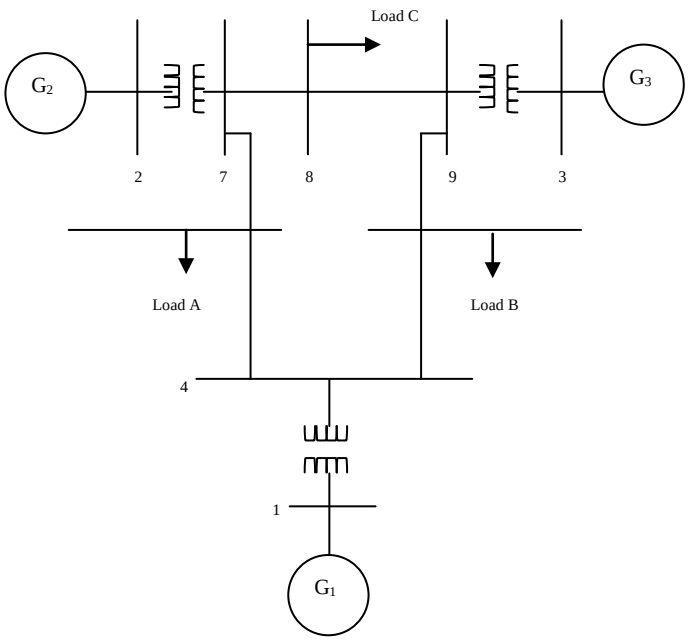

Figure 1 : Single-line diagram of three-machine nine-bus system

b) System Model and PSS Structure

A power system can be modeled by a set of nonlinear differential equation as:

$$\dot{X} = f(X, U)$$

Where X is the vector of the state variables and U is the vector of input variables. In this study, $X = [\delta, \omega, E_q^{'}, E_{fd}]^T$ and U is the PSS output signals.

In the design of PSSs, the linearized incremental models around an equilibrium point are usually employed [28, 29]. Hence, the state equation of a power system with n machines and n_{PSS} stabilizers can be written as:

$$\Delta\dot{X} = A\Delta X + BU$$

Where A is a 4n x 4n matrix equals $\partial f/\partial X$, while B is 4n x n_{PSS} matrix and equals $\partial f/\partial U$. Both A and B are evaluated at the equilibrium point. ΔX is a 4n x 1 state vector while U is n_{PSS} x 1 input vector.

A widely used conventional lead-lag PSS is considered in this study. It can be described as [29, 30].

$$U_i = K_i \frac{sT_w}{1+sT_w} \frac{(1+sT_{1i})}{(1+sT_2)} \frac{(1+sT_{3i})}{(1+sT_4)} \Delta\omega_i$$

Where T_w the washout time is constant, U_i is the PSS output signal at the ith machine, and $\Delta\omega_r$ is the speed deviation of this machine. The time constant T_w, T_2 *and* T_4 are usually prespecified [30]. The stabilizer gain K_i and time constants T_{1i}

And T_{3i} still need to be optimized.

c) Objective function and PSS tuning

To increase the system damping to electromechanical modes, an objective function J defined below is considered.

$J = max\{\text{Re}(\lambda_i), i \in \text{set of electromechanical modes}\}$

Where $\text{Re}(\lambda_i)$ is the real part of the ith eigen value associated with electromechanical modes. This objective function is proposed to shift these eigenvalues to the left of s-plane in order to improve the system damping factor and setting time and insure some degree of relative stability.

The problem constraints are the optimized parameter bounds. Therefore, the design problem can be formulated as the following optimization problem.

Minimize J

Subject to

$$K_i^{min} \leq K_i \leq K_i^{max}$$
$$T_{1i}^{min} \leq T_{1i} \leq T_{1i}^{max}$$
$$T_{3i}^{min} \leq T_{3i} \leq T_{3i}^{max}$$

Typical ranges of these parameters are [0.01-50] for K_i and [0.01-1.0] for T_{1i} [1]. The time constants T_w, $T_2$and T_4 are set as 5, 0.05 and 0.05 s respectively [31].

The proposed approach employs NRGA algorithm to solve this optimization problem and search for optimal set of PSS parameters, $\{K_i, T_{1i}, T_{3i}, i = 1, 2, \ldots, n_{PSS}\}$.

Genetic Algorithm

The genetic algorithm (GA) is an optimization and stochastic global search technique based on the principles of genetics and natural selection. A GA allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the "fitness" (i.e., minimizes the cost function). The method was developed by John Holland (1975) over the course of the 1960s and 1970s and finally popularized by one of his student, David Goldberg (1989) [7-8]. Generally in GA, there are three basic operations like reproduction, crossover and mutation.

a) Reproduction

it is a process in which a new generation of population is formed by selecting the fittest individuals in the current population. This is the survival of the fittest mechanism. Strings selected for reproduction are copied and entered to the mating pool.

b) Crossover

Mating is the creation of one or more offspring from the parents selected in the pairing process. The current members of the population limit the genetic makeup of the population. The most common form of mating involves two parents that produce two offspring. The new offspring may replace the weaker individuals in the population. With the cross over operation, GA is able to acquire more information with the generated individuals and the search space is thus extended and more complete.

c) Mutation

Random mutations alter a certain percentage of the bits in the list of chromosomes. Mutation is the second way a GA explore a cost surface. It can introduce traits not in the original population and keeps the GA from converging too fast before sampling the entire cost surface.

Recent research has identified some drawbacks in GA performance [32]. Limitations of genetic Algorithm in power system stabilization

- Slow convergence
- It lacks rank based fitness function

So the proposed approach uses the non dominated ranked genetic algorithm for the optimization purpose. The main advantages of using non dominated ranked genetic algorithm are that it converges very significantly than GA. Moreover, it is provides rank based fitness function and it is quicker than GA.

Non-Dominated Ranked Genetic Algorithm

At first, a random parent population P is formed. The sorting of the population is in accordance with the non-domination. Every solution is allocated a fitness (or rank) equivalent to its non-domination level. Non-domination level of 1 represents the best level, 2 represents the next-best level, etc.

Therefore, minimization of fitness is implicit. Initially, the normal Ranked accorded Roulette wheel choosing, recombination, and mutation operators are applied to generate an offspring population Q of size N. As elitism is initiated by contrasting present population with earlier obtained best nondominated results, the process is varied after the starting generation. Initially the ith generation of the presented algorithm as shown in below is explained.

The algorithm represents that Non-Dominated Ranked Genetic is simple and straightforward. Initially, a combined population P∪Q is created. The mixed population is of size 2N then obtained; the mixed population is sorted based on the non-domination. As every previous and present population members are incorporated in the mixed population elitism is guaranteed. This process will choose N solutions out of 2N.

The new population of size N is utilized for choosing. Next, two tiers ranked dependent roulette wheel selection is used, one tier to choose the front and the other to choose solution from the front, here the results obtained for the finest nondominated set F1 have the higher probabilities to be chosen. Therefore, results from the set F2 are selected with small probability than results from the set F1 and so on. After that crossover and mutation are used to generate a new population P of size N. The diversity between non-dominated results is established by the second tier of ranked dependent roulette wheel selection that ranks the results according to their crowding distance. The results with lesser

crowding distance will have the higher probabilities.

As solutions contend with their crowding distance, no extra niching attribute is needed. Even though the crowding distance is computed in the objective function space, it can also be obtained in the parameter space, if required. The objective function space niching is utilized in this proposed approach. The NRGA algorithm is shown in figure 2.

Algorithm NRGA

1 : Initialize Population P
2 : { Generate random population – size N
3 : Evaluate Objective Values
4 : Assign Rank (level) Based on Pareto dominance Sort
5 : }
6 : { Ranked based Roulette Wheel Selection
7 : Recombination and Mutation }
8 : **for** i=1 to g do
9 : **for** (PUQ) **do**
10 : Assign Rank (level) based on Pareto-sort
11 : Generate sets of non-dominated fronts
12 : Calculate the crowding distance between members of each front
13 : **end for**
14 : (elitist) Select the members of the combined population based on least dominated N solution ti make the population of the next generation. Ties are resolved by taking the less crowding distance
15 : Create next generation
16 : { Ranked based Roulette Wheel Selection
17 : Recombination Mutation}
18 : **end for**

Figure 2 : Non-Dominated Ranked Genetic Algorithm

This proposed NRGA provides significant convergence and stabilization for the multi-machine power system.

IV. Experimental Results

The evaluation for the power system stabilization is presented in this section. The power system stabilization using proposed optimization technique is evaluated by comparing with the power system stabilization using Genetic Algorithm. The controller parameters such as lower bound and upper bound are altered to 0 and 60 respectively.

Table 1 shows the loading of the generators G1, G2 and G3 in the proposed multi-machine power system.

Table 1 : Generator loading in pu

Gen	Case 1		Case 2		Case 3	
	P	Q	P	Q	P	Q
G_1	0.71	0.25	2.19	1.06	0.34	1.10
G_2	1.62	0.07	1.92	0.55	2.00	0.56
G_3	0.84	-0.10	1.28	0.36	1.51	0.38

Table 2 shows the loads used in A, B and C for the proposed multimachine power system stabilization approach.

Table 2 : Generator loading in pu

Load	Case 1		Case 2		Case 3	
	P	Q	P	Q	P	Q
A	1.24	0.51	2.01	0.80	1.50	0.91
B	0.90	0.30	1.81	0.61	1.21	0.81
C	1.00	0.34	1.51	0.60	1.00	0.52

Table 3 : Electromechanical Mode Eigen Values

Case 1			Case 2			Case 3		
Without PSS	GA	NRGA	Without PSS	GA	NRGA	Without PSS	GA	NRGA
- 0.011 ±j9.068	- 0.023± j8.921	- 0.045 ±j7.745	- 0.021± j8.907	- 0.034 ±j8.441	- 0.064 ±j8.042	0.377 ±j8.865	0.287 ±j7.925	0.201 ±j7.120
- 0.778 ±j13.86	- 0.845± j13.45	- 0.845 ±j13.16	- 0.519± j13.83	- 0.651 ±j13.01	- 0.651 ±j12.17	- 0.336 ±j13.69	- 0.636 ±j12.02	0.699 ±j11.22

Table 3 shows the electromechanical mode eigen values. The table shows the comparison of the eigen values without PSS, GA and proposed NRGA multimachine power system stabilization approach. It is observed from the table that the proposed NRGA approach has very less electromechanical mode eigen values in all the three cases when compared with the GA approach. Thus the proposed NRGA approach provides significant performance.

Figure 3 shows the comparison of the objective function of the GA and the proposed NRGA approach. It is observed from the figure that the convergence of the NRGA is better than GA. Thus the proposed NRGA is very significant when compared with the traditional GA approach.

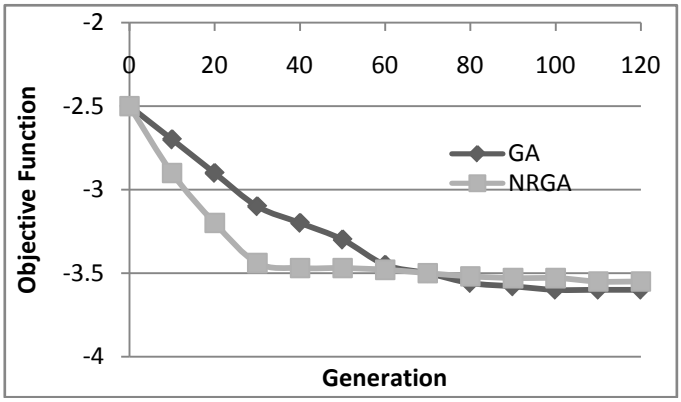

Figure 3 : Comparison of Objective Function

For evaluation, the load disturbance of 5 % is induced in the considered power system at time 1 second. Then the load disturbance induced power system undergoes stabilize using power system stabilization technique using GA and the proposed NRGA power system stabilization technique. The controller parameters are adjusted in order to stabilize the system.

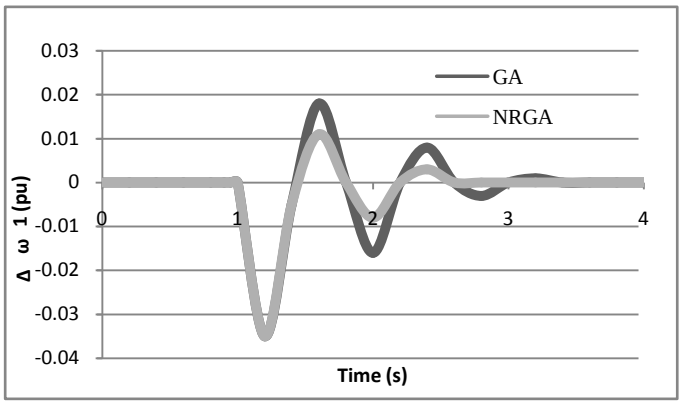

Figure 4 : System Response under fault disturbance for $\Delta\omega_1$

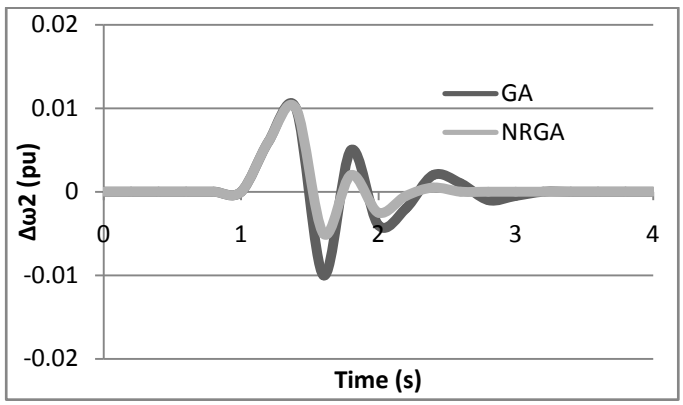

Figure 5 : System Response under fault disturbance for $\Delta\omega_2$

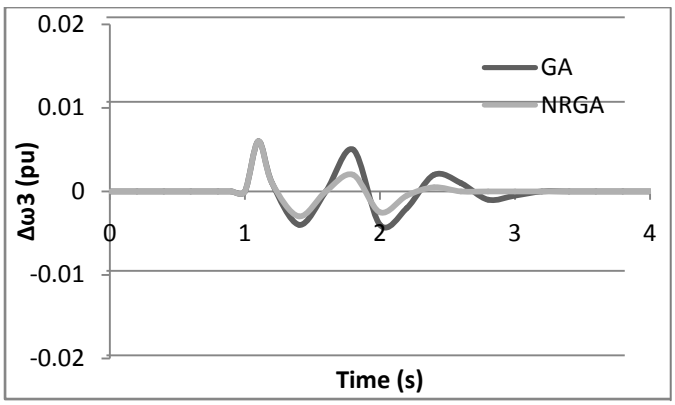

Figure 6 : System Response under fault disturbance for $\Delta\omega_3$

$\Delta\omega_1$, $\Delta\omega_2$ and $\Delta\omega_3$ deviations that occur in power system because of the introduction of 5 % load disturbance are provided in figure 4, 5 and 6 respectively. The figure depicts the stabilization behavior for using GA and NRGA for optimizing stability parameters. From the figure, it can be observed that initially the system is stable until 1 second, after that the system becomes unstable because of load disturbances. The usage of GA for stabilizing takes around 4 seconds for making the system stable, whereas, only around 3 second is required for the proposed technique to stabilize the system.

V. Conclusion

For several years Stabilization of the multi-machine power systems has been one of the most essential problems in the research area. All the existing techniques for the multi-machine power system stabilization have own advantages and disadvantages as well. The mostly used technique for stabilization is Genetic Algorithm. But, GA lacks accuracy and takes more time for convergence. To overcome those issues, this paper focuses on the use Non-Dominated Ranked Genetic Algorithm for solving power system stabilization control issues. NRGA has better convergence than the GA technique. The simulation results indicate that the proposed technique results in better stabilization than the existing techniques. The objective functions for the multi-machine power system taken into consideration shows better convergence with proposed NRGA approach. The future scope of this approach would be to use better optimization techniques which can provide a better performance.

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Detection of Mechanical Deformation in Old Aged Power Transformer Using Cross Correlation Co-Efficient Analysis Method

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Abstracts - Detection of minor faults in power transformer active part is essential because minor faults may develop and lead to major faults and finally irretrievable damages occur. Sweep Frequency Response Analysis (SFRA) is an effective low-voltage, off-line diagnostic tool used for finding out any possible winding displacement or mechanical deterioration inside the Transformer, due to large electromechanical forces occurring from the fault currents or due to Transformer transportation and relocation. In this method, the frequency response of a transformer is taken both at manufacturing industry and concern site. Then both the response is compared to predict the fault taken place in active part. But in old aged transformers, the primary reference response is unavailable. So Cross Correlation Co-Efficient (CCF) measurement technique can be a vital process for fault detection in these transformers. In this paper, theoretical background of SFRA technique has been elaborated and through several case studies, the effectiveness of CCF parameter for fault detection has been represented.

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GJRE-J Classification : *FOR Code: 090607*

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Asif Islam[α], Aminul Hoque[Ω]

Abstract - Detection of minor faults in power transformer active part is essential because minor faults may develop and lead to major faults and finally irretrievable damages occur. Sweep Frequency Response Analysis (SFRA) is an effective low-voltage, off-line diagnostic tool used for finding out any possible winding displacement or mechanical deterioration inside the Transformer, due to large electromechanical forces occurring from the fault currents or due to Transformer transportation and relocation. In this method, the frequency response of a transformer is taken both at manufacturing industry and concern site. Then both the response is compared to predict the fault taken place in active part. But in old aged transformers, the primary reference response is unavailable. So Cross Correlation Co-Efficient (CCF) measurement technique can be a vital process for fault detection in these transformers. In this paper, theoretical background of SFRA technique has been elaborated and through several case studies, the effectiveness of CCF parameter for fault detection has been represented.

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I. Introduction

Nowadays, reliability is an inevitable part of power system studies and operation, due to significant increase in the number of industrial electrical consumers. Power transformer is one of the major and critical elements in power system [1] in the area of reliability issue, since their outage may result in costly and time - consuming repair and replacement. Power transformers are specified to withstand the mechanical forces arising from both shipping and subsequent in-service events, such as faults and lightning. Once a transformer is damaged either heavily or slightly, the ability to withstand further incidents or short circuit test [2] becomes reduced. There is clearly a need to effectively identify such damage. A visual inspection is costly and does not always produce the desired results or conclusion [3]-[5]. During a field inspection, the oil has to be drained and confined space entry rules apply. Often, a complete tear down is required to identify the problem. An alternative method is to implement field-diagnostic techniques that are capable of detecting damage such as Frequency Response Analysis (FRA) [6]-[10].

There are basically two techniques used for FRA measurements on power transformers; Low Voltage Impulse (LVI) based FRA and Sweep Frequency Response Analysis (SFRA) [11]. The two techniques are also termed FRA-I (impulse method) and FRA-S (swept-frequency method) [12]. The common strategy for both methods [13] is that the transformer impedance is measured at several different frequencies. The impedance will vary from one frequency to another due to the internal constitution of the transformer.

II. SFRA Theory

When a transformer is subjected to FRA testing, the leads are configured in such a manner that four terminals are used. These four terminals can be divided into two unique pairs [14], one pair for the input and the other pair for the output. These terminals can be modeled in a two-terminal pair or a two-port network configuration. Figure 1 illustrates a two-port network where z11, z22, z12 and z21 are the open-circuit impedance parameters.

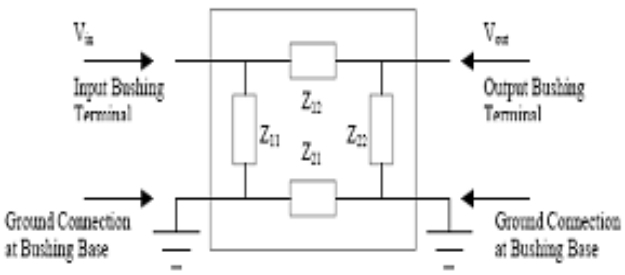

Figure 1 : Two port network

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The transfer function of this network [15] is represented in the frequency domain and is denoted by the Fourier variable H(jω), where (jω) denotes the presence of a frequency dependent function and ω = 2πf. The Fourier relationship for the input/output transfer function is given by Equation 1

$$H(j\omega) = \frac{V_{output}\ (j\omega)}{V_{input}\ (j\omega)} \qquad (1)$$

When a transfer function is reduced to its simplest form, it generates a ratio of two polynomials. The main characteristics, such as half-power and resonance of a transfer function occur at the roots of the polynomials. The roots of the numerator are referred to as "zeros" and the roots of the denominator are "poles" [16]. Zeros produce an increase in gain while poles cause attenuation.

The goal of FRA is to measure the impedance model of the test specimen. When the transfer function H(jω) is measured, it does not isolate the true specimen impedance Z(jω). The true specimen impedance Z(jω) is the RLC network which is positioned between the instrument leads and it does not include any impedance supplied by the test instrument. Figure 2 illustrates the RLC circuit with shunt resistor.

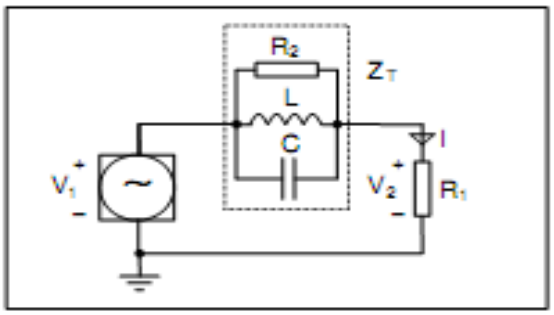

Figure 2 : RLC circuit and shunt resistor

From the figure, Voltage division formula gives

$$V_2(j\omega) = V_1(j\omega).\frac{R1}{R1 + \frac{1}{\frac{1}{R2} + \frac{1}{j\omega L} + j\omega C}}$$

The transfer function is :

$$H(j\omega) = \frac{V_2(j\omega)}{V_1(j\omega)} = \frac{R_1}{R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{j\omega L} + j\omega C}} = \frac{R_1\left(\frac{1}{R_2} + \frac{1}{j\omega L} + j\omega C\right)}{R_1\left(\frac{1}{R_2} + \frac{1}{j\omega L} + j\omega C\right) + 1} \cdot \frac{j\omega L}{j\omega L}$$

$$= \frac{R_1\left(j\omega\frac{L}{R_2} + 1 - \omega^2 LC\right)}{R_1\left(j\omega\frac{L}{R_2} + 1 - \omega^2 LC\right) + j\omega L}$$

If R2 would be removed from the circuit then the term $j\omega\frac{L}{R_2}$ disappears from the expressions above. It is now easy to see where the resonant frequency must occur : $1 - \omega_r^2 LC = 0 \Rightarrow \omega_r = \frac{1}{\sqrt{LC}}$

At resonant frequency the transfer function is

$$H(j\omega_r) = \frac{R_1\left(j\frac{L}{R_2\sqrt{LC}} + 1 - 1\right)}{R_1\left(j\frac{L}{R_2\sqrt{LC}} + 1 - 1\right) + j\frac{L}{\sqrt{LC}}} = \frac{\frac{R_1}{R_2}}{\frac{R_1}{R_2} + 1} = \frac{R_1}{R_1 + R_2}$$

What is really measured over the shunt resistor R1 is the current I. So, the transfer function describes the admittance : $Y = \frac{I}{V_1}$. The impedance is thus : $Z = \frac{V_1}{I}$

The impedance at resonance (including the shunt resistor) is $Z(\omega_r) = \frac{R_1 + R_2}{R_1}$

The preferred method of engineers is to use the Bode Diagram. The Bode Diagram plots the magnitude and phase as follows:

$$A(dB) = 20\log10(H(j\omega))$$

$$A(\Theta) = \tan - 1(H(j\omega))$$

The Bode Diagram [17] takes advantage of the asymptotic symmetry by using a logarithmic scale for frequency. It is more advantageous to plot H(s) logarithmically over large frequency spans. The logarithmic plot helps to maintain consistent resolution. Plots ranging from 10 Hz to 10 MHz can be displayed as a single plot if they are formatted logarithmically. Fig. 3 shows a typical response for a high voltage star connected winding. The frequency range of interest is between 20 Hz and 2 MHz.

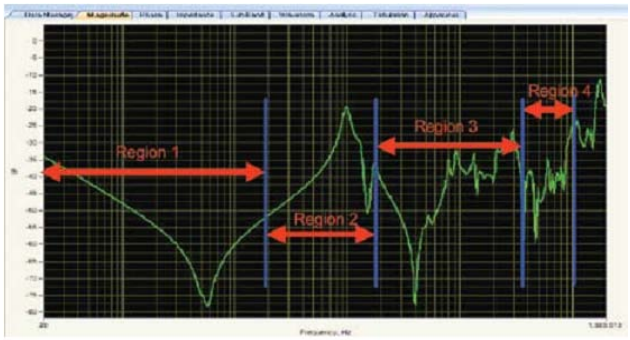

Figure 3 : Frequency Analysis Bands

Experience has shown that different sub-bands are dominated [18] by different internal components of the transformer and are subsequently more sensitive to different types of failures, as summarized in Table 1. Measurements above 2 MHz tend to be dominated by variations in grounding practices for test leads.

Region	Frequency Sub-Band	Component	Failure Sensitivity
1.	< 2 kHz	Main core bulk and winding inductance	Core deformation, open circuits, shorted turns and residual magnetism
2.	2 kHz to 20 kHz	Bulk component and shunt impedances	Bulk winding movement between windings and clamping structure
3.	20 kHz to 400 kHz	Main windings	Deformation within the main or top windings
4.	400 kHz to 1 MHz	Main windings, top windings and internal leads	Movement of the main & top winding, ground impedance variations

Table 1 : Frequency sub-band sensitivity

III. Measurement Procedure

The FRAX "Generator" (Gen.) generates a sinusoidal voltage at a selected frequency and measures the input voltages, amplitude and phase, on two input channels "Reference" (Ref.) and "Measure" (Meas.). The instrument stores "Amplitude" and "Phase" data for both "Reference" channel and "Measure" channel as well as the ratio "Measure" divided by "Reference". The values can be plotted and exported as Magnitude, Phase, Impedance, Impedance-Phase, Admittance and more. The "Custom models" function makes it possible to calculate almost any parameter based on the measured/stored data. FRAX uses the sine correlation technique [19]. This means that the input voltages are multiplied by a sine and a cosine, and then averaged over an integer multiple of the interval of time. The sine, cosine and the voltage applied have exactly the same frequency. The sine correlation technique is well known and is suitable for Sweep Frequency Response Analysis (SFRA) measurements. Since the signals on the two input channels are treated the same way, the phase resolution between these two channels is very high. The rejection of DC offset and harmonics - referred to as the applied voltage - are in theory infinite. By increasing the integration cycles, the rejection gradually improves.

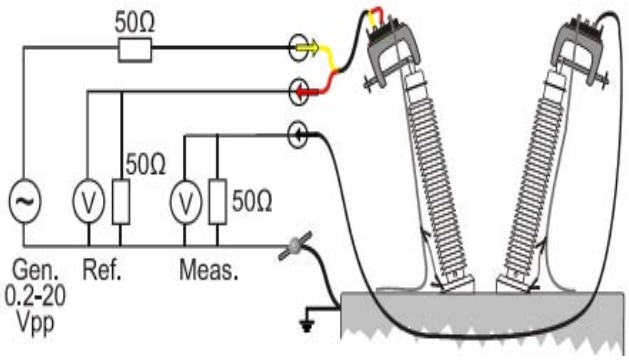

Figure 4 : SFRA Terminal Connection

The IF Bandwidth is commonly used as a parameter defining the bandwidth around the applied signal analyzed. An IF bandwidth of 10% of the active frequency is equivalent to 12 cycles of integration. When considering SFRA measurements, winding measurements realistically consist of three categories. The winding categories are high-voltage, low-voltage, inter winding.

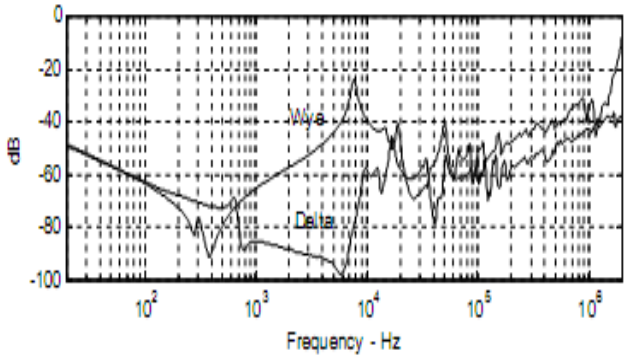

Figure 5 : HV winding response

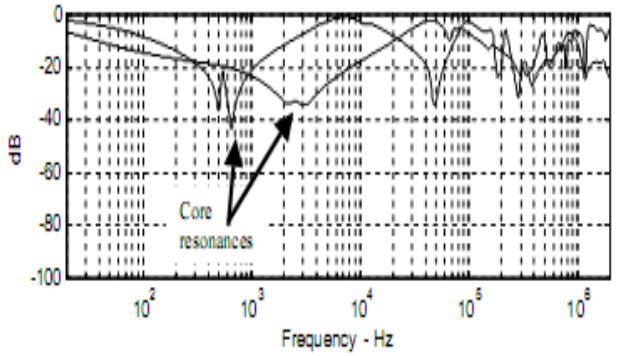

Figure 6 : LV winding response

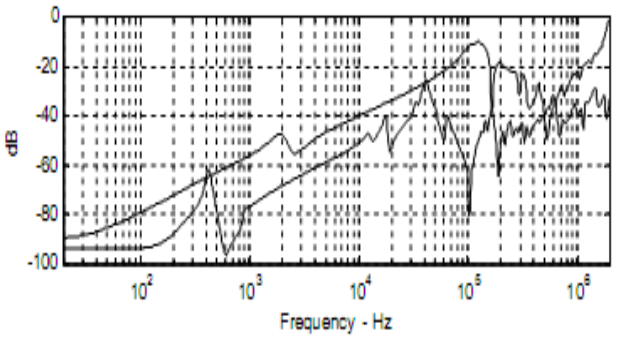

Figure 7 : Inter winding response

Figure 8 presents a high-voltage winding trace, a low-voltage winding trace and an inter-winding trace together from a common test specimen. This illustrates their general relationship.

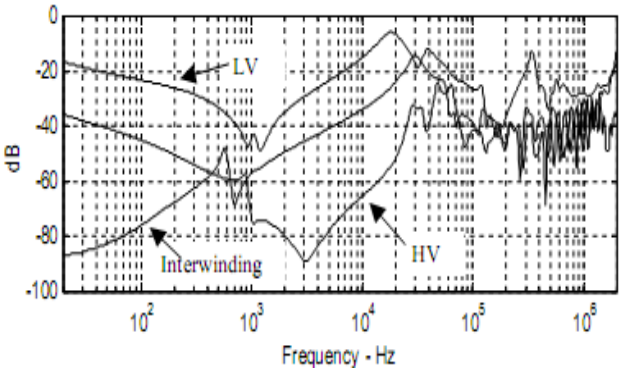

Figure 8 : Complete response

IV. Response Analysis

For the analysis of a measured response, the response in compared with one of the following:

- An earlier result [20] for the same phase tested with the same tap changer position.
- If no earlier result is available then another phase [18] of the same transformer, tested at the same occasion.
- The same phase, same tap changer position but on a unit believed to be of the same design group and made at the same factory

It is found that Cross Correlation [20] coefficient (CCF) is the most reliable statistical indicator to extract information from comparison method. The CCF is defined as:

$$CCF = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum(X_i-\bar{X})^2 * \sum(Y_i-\bar{Y})^2}}$$

Where Xi and are Yi are the two series (or trace in the case of SFRA) being compared at each individual frequency 'i' and X-bar and Y-bar are the means.

Equation 1 assumes two real series. In the case of signal processing the math becomes a little more involved, but the end results is still a coefficient between 1 and -1. In SFRA analysis negative CCF are not common but they do occur on occasion. Regardless, negative correlation coefficients are not considered acceptable when trying to look for deviations between traces.

Decision	CCF
Good match	0.95 – 1.0
Close match	0.90 – 0.94
Poor match	≤0.89
No or very poor match	≤0.0

Table 2 : Outcome of CCFs value

Normalizing the results to the individual power spectrums is what allows this resulting waveform to be expressed in a simple single coefficient. Table 2 helps provide a rough estimate of what the CCF means in simple language.

Case	Capacity MVA	HT Voltage kV	LT Voltage kV	Year of manufacture
1	41.67	132	33	1998
2	14	33	11.6	1991

Table 3 : Case study of Fault condition

a) 41.67 MVA, 132/33 kV, 3φ Power Transformer at 132 kV Substation

The results here are from a three phase 25/41.67 MVA, 132/33 kV (vector group Dyn-1) power transformer manufactured by EMCO Transformers Ltd. (Maharastra, India) at 1998 for Bangladesh Power Development Board (BPDB) 132 kV sub-station. The transformer had tripped out of service on protection. No reference factory results were available for this unit. The phase-to-phase HV results didn't show typical variations from standard HV delta winding response. An overall look at the LV winding has showed several shifts between 200 kHz and 2 MHz. This is shown in figure 9 where it is clear that H3-H0 has consistently shifted at higher frequencies with respect to H2-H0 and H1-H0.

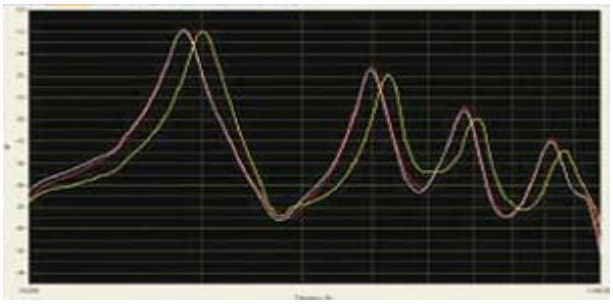

Figure 9 : Close zoom of LV winding response (100 kHz-1 MHz)

This is an indication of axial winding movement at X3 (Blue/C phase) phase. From CCF analysis method results (Table-4), this prediction can be more confirmed.

Frequency Sub-band	CCF results		
	X1-X0, X2-X0	X2-X0, X3-X0	X3-X0, X1-X0
0 – 2 kHz	0.9981	0.9925	0.9954
2 kHz – 20 kHz	0.9943	0.9868	0.9736
20 kHz – 400 kHz	0.9853	0.7263	0.7681
400 kHz – 1 MHz	0.9892	0.9475	0.9424

Table 4 : Test result of LV winding keeping HV open

From the table, it is clearly visible that CCF values of phase A and phase B fulfill "Good Match" criteria in all 4 frequency sub-band regions. CCF values of phase C both with phase A or phase B meet up either "Good Match" or "Close Match" criteria in all bands except region 3. At region 3, both CCF values of phase C (0.7263 and 0.7681) drops down vigorously at "Poor Match" level.

Figure 10 : Damaged LV (phase-C) coil

Removing the transformer top cover, the active part was brought out and after a through physical inspection, the prediction became true with damage of LV (phase C) coil.

b) 14 MVA, 33/11.6 kV, 3φ Power Transformer at 33 kV Substation

The subjected transformer was running at Dhaka Power Distribution Company (DPDC). It is a 10/14 MVA, 33/11.6 kV (vector group - YNd11) power transformer manufactured by Brush Transformers Ltd. (Loughborough, England) at 1991. Due to its age of 20 years, frequency response of this transformer was taken to predict its aging effect. At first, test was carried on HV side keeping LV side open followed by LV side shorte Corresponding Bode Plot response has been shown in figure 11 and 12.

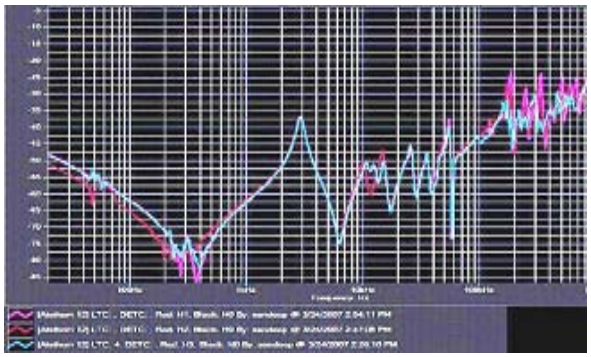

Figure 11 : HV winding response (LV open)

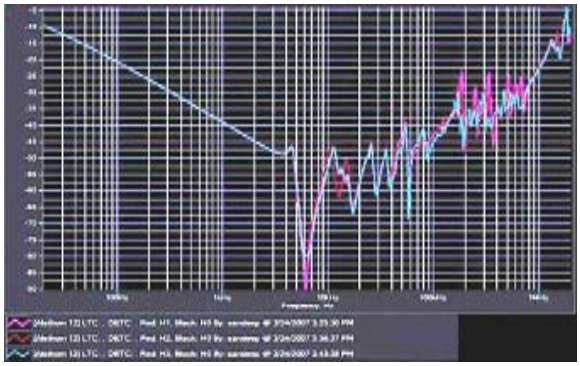

Figure 12 : HV winding response (LV short)

Frequency Sub-band	CCF results		
	X1-X0, X2-X0	X2-X0, X3-X0	X3-X0, X1-X0
0 – 2 kHz	0.7981	0.7825	0.9914
2 kHz – 20 kHz	0.9743	0.9841	0.9736
20 kHz – 400 kHz	0.9523	0.9267	0.9081
400 kHz – 1 MHz	0.8394	0.8975	0.8427

Table 5 : CCF of HV winding keeping LV open

Frequency Sub-band	CCF results		
	X1-X0, X2-X0	X2-X0, X3-X0	X3-X0, X1-X0
0 – 2 kHz	0.9981	0.9925	0.9954
2 kHz – 20 kHz	0.9743	0.9861	0.9786
20 kHz – 400 kHz	0.9354	0.9283	0.9217
400 kHz – 1 MHz	0.8113	0.8671	0.8039

Table 6 : CCF of HV winding keeping LV open

From the CCF result (Table-5), it is easily viewable that the matching is very poor at low frequency region (0-2 kHz). This may be due to core deformation as a result of axial stress because the transformer is running for a long time (20 years). Again, poor matching at higher region (400 kHz-1 MHz) indicates main coil deformation either by radial stress or by axial stress. This deformation is more severe for A phase (Red phase).

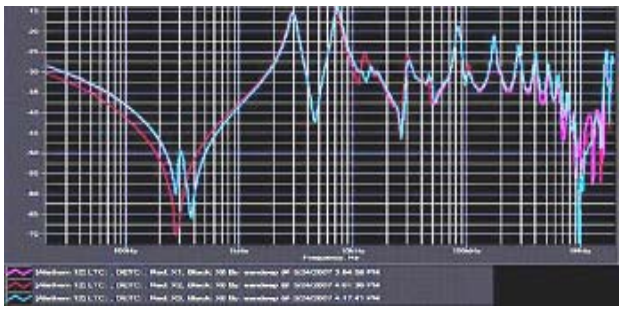

Figure 13 : LV winding response (HV open)

Frequency Sub-band	CCF results		
	X1-X0, X2-X0	X2-X0, X3-X0	X3-X0, X1-X0
0 – 2 kHz	0.8381	0.8325	0.9907
2 kHz – 20 kHz	0.9943	0.9921	0.9936
20 kHz – 400 kHz	0.9825	0.9867	0.9781
400 kHz – 1 MHz	0.8493	0.9275	0.8027

Table 7 : CCF of LV winding keeping HV open

From LV winding response (Figure 13) and corresponding CCF calculation (Table 7), the previous assumption becomes stronger. Poor matching at low frequency region (0-2 kHz) and high frequency region (400 kHz-1 MHz) again spans the prediction of core damage and main winding movement firmly. After replacing the transformer from the system, it was dissected and both the prediction became true.

VI. Conclusion

Sweep frequency response analysis method has been applied to a number of three phase and single phase power transformers of different vector groups. This method is also applicable for mechanical deformation and damage diagnosis in distribution transformers. The parameter Cross Correlation Co-efficient (CCF) is found to vary significantly and consistently with mechanical displacements taken place in transformers. So it can be considered as the most effective indicator to predict the internal physical condition of the active part of a transformer.

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Improved Chan-Ho Model For Indoor Mobile User Location Estimation Using TDOA Information

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Abstracts - The indoor location detection technology based on TDOA is one of the key technologies in 3G telecommunication for researchers. In this work, TDOA positioning method based on modified Chan-Ho algorithm for mobile network is proposed. The performance of Chan-Ho method is totally dependent on distance between base station and mobile station. Here mathematical model of TDOA is established for closed environment of having size 750m x 750m. This method makes use of TDOA to minimize the error in positioning of mobile station. The proposed method uses extra term to estimate accurate distance as compared with original Chan-Ho method. Our simulation results shows that the error is less and has advantage over other methods.

Keywords :Time difference of arrival (TDOA) , Chan-Ho, user location, Hyperbolic, Mobile station, Home base station.

GJRE-J Classification : FOR Code: 100504, 100501

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Improved Chan-Ho Model For Indoor Mobile User Location Estimation Using TDOA Information

B R Jadhavar[α], T R Sontakke[Ω]

Abstract - The indoor location detection technology based on TDOA is one of the key technologies in 3G telecommunication for researchers. In this work, TDOA positioning method based on modified Chan-Ho algorithm for mobile network is proposed. The performance of Chan-Ho method is totally dependent on distance between base station and mobile station. Here mathematical model of TDOA is established for closed environment of having size 750m x 750m. This method makes use of TDOA to minimize the error in positioning of mobile station. The proposed method uses extra term to estimate accurate distance as compared with original Chan-Ho method. Our simulation results shows that the error is less and has advantage over other methods.

Keywords : Time difference of arrival (TDOA) , Chan-Ho, user location, Hyperbolic, Mobile station , Home base station.

I. Introduction

The positioning systems that are used to track and determine the users location in 3G telecommunication systems have gained increasing interest. In indoor location systems global positioning system (GPS) is not efficient due to obstruction and shielding of satellite signals. In indoor environment, there are many positioning systems based on different technologies such as received signal strength, ultrasound and Infrared, video surveillance. The basic characteristics of signals are utilized such as received signal strength (RSS), angle of arrival (AOA) estimation, time of arrival (TOA) estimation and time difference of arrival (TDOA). In the past, time delay estimation has been proposed and implemented by Knapp and Carter (1976) and Aarabi (2001) [10].

Different techniques have been proposed with different complexcity and restrictions. Carter's focused on beam forming [1], requires a search over a set of possible target locations. Hahn's method [2] assumes distant source. Abel and Smith [3] provide an explicit solution that can achieve the Cramer -Rao Lower Bound (CRLB) in the small error region. The situation is more complex when sensors are distributed arbitrarily. Here emitter position is determined from the intersections of a set of hyperbolic curves defined by TDOA estimates. Solution is not easy as the equation are non linear. Fang [4] gave an exact solution when number of TDOA measurements are equal to number of unknowns. This solution cannot make use of extra measurements, available when there are extra sensors, to improve position accuracy. The more general situation with extra measurements was considered in [5, 6, 8, 9]. The divide and conquer (DAC) method [7] by Abel can achieve optimum performance, but it requires sufficiently large information. To obtain a precise position estimate at reasonable noise levels, the Taylor-series method is commonly employed. It is an iterative method. It starts with an initial guess and improves the estimate at each step by determining the local linear least-squares (LS) method. Selection of such a starting point is not simple in practice. Moreover, convergence of the iterative process is not assured. It is also computationally intensive as LS computation is required in each iteration.

The AOA requires antenna arrays at each node which increases the complexity of the existing system, and performs worse in multipath environment. In this case accurate estimation of TOA from received communication signals are required. Indoor multipath interference is the main factor that limits deploying indoor positioning systems, the multipath is sever and complex which leads to inaccurate estimate of the TOA using conventional techniques.

TOA (Time of Arrival) method is to calculate a position using a measured value of an arrival time of electric wave and TDOA method uses an arrival time lag of electric waves that are sent from different base stations (BSs). Among these, TOA and TDOA are widely used methods in positioning system.

TDOA estimates the difference in arrival times of the signals between synchronized reference nodes. In TDOA absolute time of transmission is not important but only synchronization of nodes is necessary. Each range determines a hyperbola. For this technique at least three nodes are required for positioning in two dimension plane. The intersection points of three hyperbolas give the position of moving object. Chan-Ho algorithm [12]

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is effective technique in locating object based on intersections of hyperbolic curves defined by the time differences of arrival of signal received at number of sensors is proposed. This can achieve high accuracy however it cannot work efficiently if the measurement has large NLOS errors.

Both TOA and TDOA are technologies in radio location systems based on cellular networks. TOA is implemented by calculating the time of signal arrival from mobile station and base transreceiver station directly. However TDOA calculates the time difference of signal arrival between two base stations. The cross-correlation of the two versions of the signal at pairs of base stations is done and the peak of the cross-correlation output gives the time difference for the signal arrival at those two base stations. This method offers many advantages over other competing techniques. Since, all the processing takes place at the infrastructure level, no modifications are needed in the existing handsets. In this work we present modified location method based on Chan-Ho algorithm to solve hyperbolic equations which results in reduced positioning error.

This paper is organized as follows. In section two, mathematical model for hyperbolic TDOA equations is explained. in section three proposed improved Chan-Ho model is described. In section four simulation method and conclusion in section five is given.

II. Mathematical Model for Hyperbolic TDOA Equations

This is general model for two dimensional location position estimation of source having M base stations. Referring all TDOAs to the first base station (BS), which is assumed to be base station controlling the call and first to receive transmitted signal. Assuming real coordinates of source be (x, y) and that of i^{th} base station to be (X_i, Y_i).Therefore the distance between source and BSi is

$$R_i = \sqrt{(X_i - x)^2 + (Y_i - y)^2} = \sqrt{X_i^2 + Y_i^2 - 2X_i x - 2Y_i y + x^2 + y^2} \quad (1)$$

The difference between base stations with respect to the base station where the signal arrives first is

$$R_{i,1} = cd_{i,1} = R_i - R_1 \quad (2)$$

$$= \sqrt{(X_i - x)^2 + (Y_i - y)^2} - \sqrt{(X_1 - x)^2 + (Y_1 - y)^2} \quad (3)$$

Where c is speed of propagation of signal, $R_{i,1}$ is range difference between first base station and i^{th} base station, R_1 is the distance between first base station and source and $d_{i,1}$ is the estimated TDOA between first base station and i^{th} base station. This defines the set of nonlinear hyperbolic equations whose solution gives 2-D co-ordinates of the source. The solution of nonlinear equations is difficult hence these equation must be linearized [14]. Nonlinear equations can be transformed into another set of equations. Rearranging (3) into

$$R_i^2 = (R_{i,1} + R_1)^2 \quad (4)$$

Equation (1) can be rewritten as

$$R_{i,1}^2 + 2R_{i,1}R_1 + R_1^2 = K_i^2 - 2X_i x - 2Y_i y + x^2 + y^2 \quad (5)$$

Where, $K_i^2 = X_i^2 + Y_i^2$

At $i = 1$, subtracting (1) from (5), results in

$$R_{i,1}^2 + 2R_{i,1}R_1 + R_1^2 = X_i^2 + Y_i^2 - 2X_{i,1}x - 2Y_{i,1}y + x^2 + y^2 \quad (6)$$

Where, $X_{i,1} = X_i - X_1$ and $Y_{i,1} = Y_i - Y_1$

The set of equations (6) are nonlinear with source location (x, y) and range of first receiver to source R_1 is unknowns and can be easily handled.

These are nonlinear equations whose solution gives (x, y). These equations are difficult to solve. Linearizing (2) by Taylor series method of expansion and solving them iteratively is one way. With the set of TDOA estimates$d_{i,1}$, the method starts with initial position guess (x_0, y_0) and compute position deviation [8] [9].

In next iteration, x_0, y_0 are then set to $x_0 + \Delta x$ and $y_0 + y_0$. The whole procedure is repeated until Δx and Δy are sufficiently small. This method has difficulty of requiring close enough starting and large computations. Again convergence is not guaranteed. An alternative method [5] [6] is to first transform equation (2) into another set of equations.

Taylor series method linearizes set of equations in (3), this method begins with initial guess and improves estimates at each iteration by determining linear least-square solution. However, it requires good initial guess and requires large computations. Fang's method [4] provides exact solution to equation (6) and his solution does not make use of redundant measurements made at additional receivers to improve position accuracy. This method has ambiguity due to inherent squaring operations.

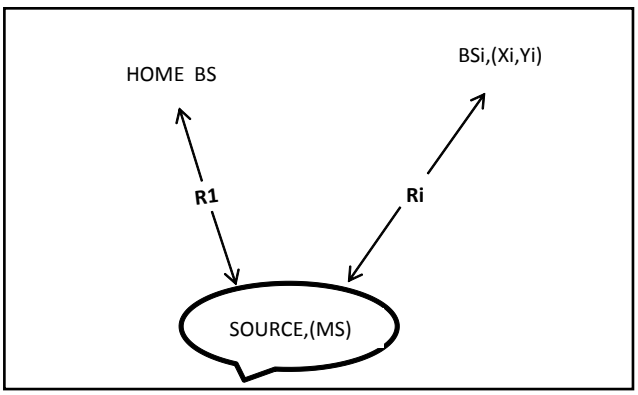

Figure 1

III. The Improved Chan-ho Model

Chan-Ho [12] gives non-iterative solution to hyperbolic position estimation problem which give optimum performance for arbitrarily placed sensors.

It gives solution in closed form. Furthermore, it provides explicit solution form that is not available in Taylor series method. This was developed for three sensors which gives two TDOA's.

From equation (1) for $i = 1$, gives

$$R_1^2 = X_1^2 + Y_1^2 - 2X_1x - 2Y_1y + x^2 + y^2 \quad (7)$$

Now combining (7) and (5), we get

$$R_{i,1}^2 2R_{i,1}R_1 = K_i^2 - K_1^2 - 2(X_i - X_1)x - 2(Y_i - Y_1)y \quad (8)$$

And finally we get

$$R_{i,1}{}^2\, 2R_{i,1}R_1 = K_i^2 - K_1^2 - 2X_{i,1}x - 2Y_{i,1}y \quad (9)$$

In Chan's algorithm for M=3. Then equation (9) becomes

$$-2X_{2,1}x - 2Y_{2,1}y = 2R_{2,1}R_1 + R_{2,1}^2 - K_2^2 - K_1^2 \quad (10)$$

$$-2X_{3,1}x - 2Y_{3,1}y = 2R_{3,1}R_1 + R_{3,1}^2 - K_3^2 - K_1^2 \quad (11)$$

and (10) and (11)

can be represented in the form of the following matrices:

$$-2\begin{bmatrix} X_{2,1} & Y_{2,1} \\ X_{3,1} & Y_{3,1} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} = 2\begin{bmatrix} R_{2,1} \\ R_{3,1} \end{bmatrix}R_1 + \begin{bmatrix} R_{2,1}^2 & K_2^2 & K_1^2 \\ R_{3,1}^2 & K_3^2 & K_1^2 \end{bmatrix} \quad (12)$$

Or

$$\begin{bmatrix} x \\ y \end{bmatrix} = -\begin{bmatrix} X_{2,1} & Y_{2,1} \\ X_{3,1} & Y_{3,1} \end{bmatrix}^{-1} \times \left\{ \begin{bmatrix} R_{2,1} \\ R_{3,1} \end{bmatrix}R_1 + \frac{1}{2}\begin{bmatrix} R_{2,1}^2 & K_2^2 & K_1^2 \\ R_{3,1}^2 & K_3^2 & K_1^2 \end{bmatrix} \right\} \quad (13)$$

Here (x, y) represents location of source R_1 is obtained from (7), and we get $R_{2,1}, R_{3,1}$ from (9), assuming that :

$$K_1^2 = X_1^2 + Y_1^2$$
$$K_2^2 = X_2^2 + Y_2^2 \quad (14)$$
$$K_3^2 = X_3^2 + Y_3^2$$

After getting first set of prediction of x, y it can be recalculated for better improvement. Generally this requires 2 to 5 cycles. From equation (13) it can be noted that values of x, y are dependent on R_1, which is distance between source and BS1 and the process is iterative. To improve accuracy of location of original Chan-Ho method, we adapt new term which improves accuracy. This new value uses different values resolved from two base stations to estimate right distance.

This new term specifies error on vertical and horizontal to the distance obtained.

$\frac{(x_i - xo_i)}{R_i}$; for the x-axis ratio, and

$\frac{(y_i - yo_i)}{R_i}$; for the y-axis ratio.

Where (xo_i, yo_i) is obtained coordinates of source by each BS, (x_i, y_i) coordinates of i^{th} BS. From this we get two ratios,

$$Z = \begin{bmatrix} \frac{(x_i - xo_1)}{R_1} & \frac{(x_2 - xo_2)}{R_2} \\ \frac{(y_1 - yo_1)}{R_1} & \frac{(y_2 - yo_2)}{R_2} \end{bmatrix} \quad (15)$$

To create a symmetrical matrix, we will multiply the matrix by its transpose. Then we will obtain the eigenvalues, by calculating the trace; which leads to the nearest accurate solution. The final value obtained will be corrected by taking the square root of the arithmetic mean of the trace, as following:

$$\Omega = \sqrt{\frac{tr(Z \cdot Z)}{2}} \quad (16)$$

This yields new calculation system as given below.

$$\begin{bmatrix} x \\ y \end{bmatrix} = -\begin{bmatrix} X_{2,1} & Y_{2,1} \\ X_{3,1} & Y_{3,1} \end{bmatrix}^{-1} \times \left\{ \begin{bmatrix} R_{2,1} \\ R_{3,1} \end{bmatrix}\Omega + \frac{1}{2}\begin{bmatrix} R_{2,1}^2 & K_2^2 & K_1^2 \\ R_{3,1}^2 & K_3^2 & K_1^2 \end{bmatrix} \right\} \quad (17)$$

With this method it is possible to reduce error in position.

IV. Simulation and Analysis

This simulation utilizes timing information from source to base stations only in reverse link. The simulation set up is as shown in fig. 2, having coordinates of three base stations (0, 0), (750, 433), (750, -433). The source is assumed at (100, 100). Each base station has its own radio coverage. BS1 is home base station.

Simulation setup co-ordinates					
x1	y1	x2	y2	x3	y3
0	0	750	433	750	433

Table 1

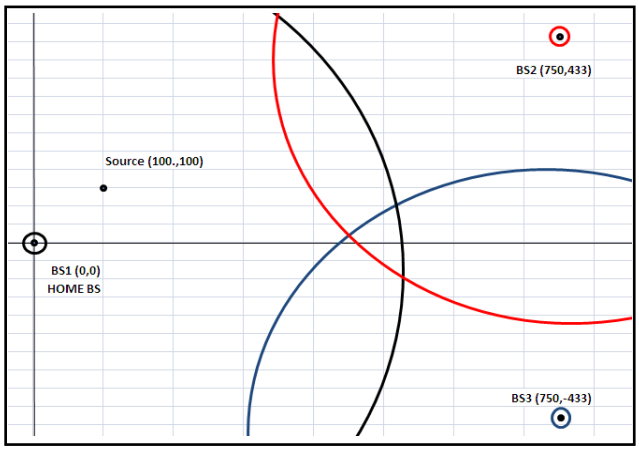

Figure 2

TDOA position location system can be implemented in two different ways. Either by subtracting the time of arrival at two BTSs, which requires the implementation of the absolute TOA mechanism or by cross-correlating the received signals from the two BTSs. Here we use cross-correlation method is used. Let $s(t)$ be the signal generated by source.

$s(t) = u(t)e^{j\omega t}$ [13] The received signal at BS from ith path is

$$s_i = r_i u(t-\tau_i)ej[(\omega 0+\omega 1i+\omega 2i)(t-\tau i)+\emptyset_i] \quad (18)$$

Where $\omega_0 = RF\ carrie,\ r_i$ = Rayleigh-distributed random variable, $\emptyset_i$ = uniformly distributed random phase, τ_i = time delay on ith path and ω_{1i} = Doppler shift of transmitting mobile unit on ith path, ω_{2i} =Doppler shift of BS which is stationary here.

The signals generated by at two base stations can be modeled as [11]

$s_1(t) = s\left\{\frac{t+D_1}{b_2}\right\}$ and $s_2(t) = s\left\{\frac{t+D_2}{b_2}\right\}$, here $D_1\ and\ D_2$

Corresponds to propagation time from source to two base stations and b_1, b_2 are time scales resulting from relative motion between source and receiver. The signals at two receivers will be $x_1(t) = s(t) + \varnothing(t)$ and $x_2(t) = s\left\{\frac{t+D}{a}\right\}+\psi(t)$, where $\varnothing(t)$ and $\psi(t)$, are additive white Gaussian noise with zero mean. Above equations takes in to account the relative velocity between source and receiver. If $\tau = \Delta t_2 - \Delta t_1$, then TDOA can be calculated from the maximum value of cross-correlation

$$R_{x_1x_2}(\tau) = \int_{-\infty}^{+\infty} x_1(\tau)x_2(t-\tau)dt \quad (19)$$

Test point		Ts	0.5
X	100	Num	10
Y	100	vx,vy	10

Num	x_predict	y_predict	Error
1	110.5532	96.4175	10.2224
2	112.75	90.067	20.1218
3	112.1963	118.3225	4.3474
4	112.655	128.2435	11.041
5	132.895	107.2847	19.3949
6	72.1096	178.2374	75.3534
7	78.974	182.8584	73.684
8	140.7444	139.0545	1.2034
9	136.6439	154.5825	12.7141
10	145.9833	154.826	6.2789
Mean Square Error			24.9043
Normalised MSE			0.036

Table 2

In original Chan-H0 method the term R_1 is used and that was obtained from BS1and modified term Ω is obtained from BS1 and BS2. Results obtained from our simulation method are much better than Chan-Ho method.

All estimated points are in the range of home base station located at (0,0). We calculated MSE which indicates higher performance. The source position was assumed to (100,100). Values of $V_x\ and\ V_y$ are changed from 5 to 15. And we obtain x, y predicted values and error is found. This indicates that MSE is less for smaller values of V_x and V_y These are indicated in tables 2 to 5.

The simulation is done in MATLAB. We get results as shown in fig. 3, fig. 4 and fig. 5. Finally cumulative probability distribution function (CDF) of absolute position error between original position and obtained values can be calculated by

$$\Delta d = \sqrt{(x-x_0)^2 + (y-y_0)^2} \quad (20)$$

Test point		Ts	0.9
X	100	Num	10
Y	100	vx,vy	5

Num	x_predict	y_predict	Error
1	112.1236	104.7796	5.2506
2	91.3624	143.3303	36.7585
3	134.2383	115.5469	13.5486
4	25.3137	231.6768	146.3062
5	147.528	141.6894	4.1654
6	151.4806	157.0849	3.9829
7	121.5537	203.5833	58.0069
8	170.7211	173.6032	2.0508
9	182.9053	178.5213	3.1264
10	201.1724	172.8173	20.4956
Mean Square Error			32.049
Normalised MSE			0.0704

Table 3

Test point		Ts	0.6
X	100	Num	10
Y	100	vx,vy	15

Num	x_predict	y_predict	Error
1	108.2665	94.9721	9.6012
2	79.8407	130.1446	35.5987
3	75.0657	138.977	45.2786
4	85.3848	136.9084	36.4527
5	39.0348	169.6687	93.5916
6	94.5704	140.7746	32.6746
7	59.391	169.8236	78.6092
8	131.6413	105.875	19.6699
9	127.3928	126.5056	0.6314
10	132.7981	126.3026	4.6368
Mean Square Error			38.5715
Normalised MSE			0.0794

Table 4

Test point		Ts	0.1
X	100	Num	10
Y	100	vx,vy	15

Num	x_predict	y_predict	Error
1	101.4991	101.5011	0.0014
2	107.5732	96.3458	8.0742
3	43.9985	149.4084	75.3472
4	105.7579	85.5612	20.4403
5	94.7848	120.6955	18.3248
6	69.0601	142.9913	52.4462
7	82.4949	136.3488	38.1109
8	92.7415	131.0388	27.0807
9	112.6631	114.5245	1.3229
10	90.782	138.2347	33.5614
Mean Square Error			30.5232
Normalised MSE			0.0543

Table 5

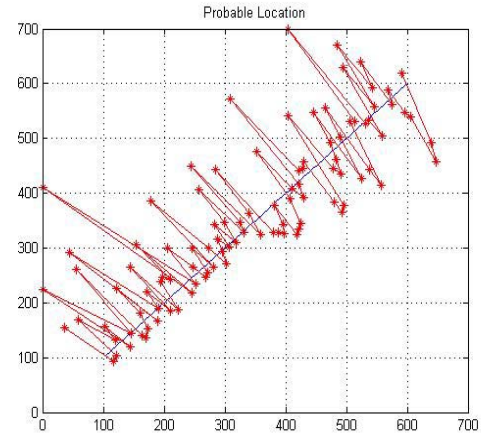

Figure 3

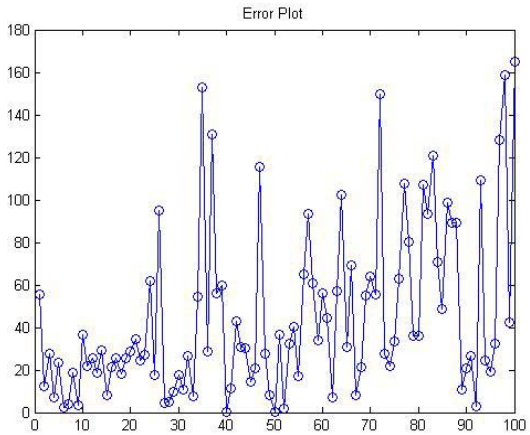

Figure 4

Figure 5

V. Conclusion

From the above table we conclude that Chan's TDOA algorithm improves the computation of mobile user locator. We perform various experiment with setting up fix mobile user location i.e. x=100, y=100 in the area of 750 X 750 plane, with two base stations at BS1 & BS2. The distance between mobile user and BS1, BS2 is calculated. We predict the probable movement of mobile user and calculate the error for each sample location and estimates its error occurred for same mobile user.

From above experiments we found that this is best set up to achieve less error in the distance calculation. We predicted Vx, Vy to be 10 and Ts=0.5. With these parameters we found that MSE is less i.e. 24.9043.

So, finally this experiments for Chan-Ho algorithm for mobile user location is less time consuming & estimates accurately its location.

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High Efficiency AlAs/GaAs/Ge Lattice Matched Multijunction Solar Cells

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Abstracts - This paper reports on the theoretical design and performance analysis of the AlAs/GaAs/Ge based triple junction solar cells. The efficiency of the lattice matched solar cells has been evaluated considering the effect of reflection coefficient. The efficiency is also compared with the lattice mismatched triple junction solar cells. The current matching is done by varying the thickness. The effect of depletion width has been taken into account in order for accuracy. However, no significant change has been observed between the results without and with considering the depletion width. The efficiency of the proposed solar cells has been found to be ~ 43.5%. The effect of reflection coefficient has also been considered. The efficiency is found to be 23% to 37% considering reflection loss. This simulated model shows that the proposed model can improve the efficiency with increasing the number of junctions.

Keywords : *Solar cells, Multifunction, AlAs/GaAs/Ge, Lattice matched, Minority carrier lifetime, Depletion width.*

GJRE-J Classification : *FOR Code:090605*

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High Efficiency AlAs/GaAs/Ge Lattice Matched Multijunction Solar Cells

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Abstract - This paper reports on the theoretical design and performance analysis of the AlAs/GaAs/Ge based triple junction solar cells. The efficiency of the lattice matched solar cells has been evaluated considering the effect of reflection coefficient. The efficiency is also compared with the lattice mismatched triple junction solar cells. The current matching is done by varying the thickness. The effect of depletion width has been taken into account in order for accuracy. However, no significant change has been observed between the results without and with considering the depletion width. The efficiency of the proposed solar cells has been found to be ~ 43.5%. The effect of reflection coefficient has also been considered. The efficiency is found to be 23% to 37% considering reflection loss. This simulated model shows that the proposed model can improve the efficiency with increasing the number of junctions.

Keywords : Solar cells, Multifunction, AlAs/GaAs/Ge, Lattice matched, Minority carrier lifetime, Depletion width.

I. Introduction

The photovoltaic solar cell is becoming widespread and very important as a clean and gentle energy source for the earth [1]. However, the efficiency of conventional and commercially available solar cells is still very low. To be competitive with the conventional energy source the efficiency of photovoltaic cell must be improved. Researchers are looking for the highly efficient photovoltaic cells from the beginning of this decade. Attempts have been made to fabricate photovoltaic cells with materials other than silicon and with no lattice mismatch. At the same time modifications in design are being carried out to reduce the reflected component of solar energy due to lattice mismatch.

Limitations of efficient use of broad solar spectrum of one junction solar cell have led to carry out much more theoretical and experimental works on the multijunction (MJ) solar cells. MJ solar cells are being being widely investigated by the researchers to increase the efficiency.

It has been shown that the theoretical Efficiency of the MJ solar cells increases as it incorporates more and more junctions [2]. However, practically there is a very little range of material that could be used to make these cells. A major challenge in achieving widespread use of solar cells lies in the identification of suitable materials with appropriate lattice and band gap matching. Besides lattice and band gap mismatches, recombination before drift, and reflection at top surface contact obstruction associated with MJ solar cells restricted the achievement of higher efficiency [3]. Due to lattice mismatch, generated carrier will be recombined in the defect of the lattice. After considering the effect of lattice mismatch the efficiency of the proposed solar cell has been found approximately 43.5% and the approach targeting 50% efficiency is proceeding using the invert lattice mismatch quantum well solar cells [4]. In this paper, the effect of antireflection on MJ solar efficiency is also studied.

II. Device Structure

Improved efficiency is the most important factor in designing the MJ solar cells. Currently used MJ solar cells are based on two or three layers of different material which are usually III-V semiconductors [5]. But lattice constants of different junctions are not same. The efficiency decreases due to the lattice mismatch. The AlAs/GaAs/Ge based solar cells have been proposed for higher efficiency.

For designing this solar cell, the materials are used in buffer layer and tunnel junction having nearly the same lattice constant and this helps to improve the efficiency [6]. These layers act as antireflection coating which reduces the refection of incident light. The schematic illustration of the proposed AlAs/GaAs/Ge MJ solar cells is shown in Fig. 1. The sub cells are arranged from bottom to top with lower to higher the band gap. Tunnel junctions are placed between the layers of a MJ to avoid the formation of junction as well as potential barrier between the layers. However dislocations at the interference of the GaAs and Ge are limiting the cell efficiency. This propagation often causes Shockly-Read-Hall recombination in the active cell regions.

To reduce the number of dislocations and cease their propagation through the upper layers of the junction cell, step graded buffer layers of InGaAs are used. Thus the constant remains the same due to small composition of In.

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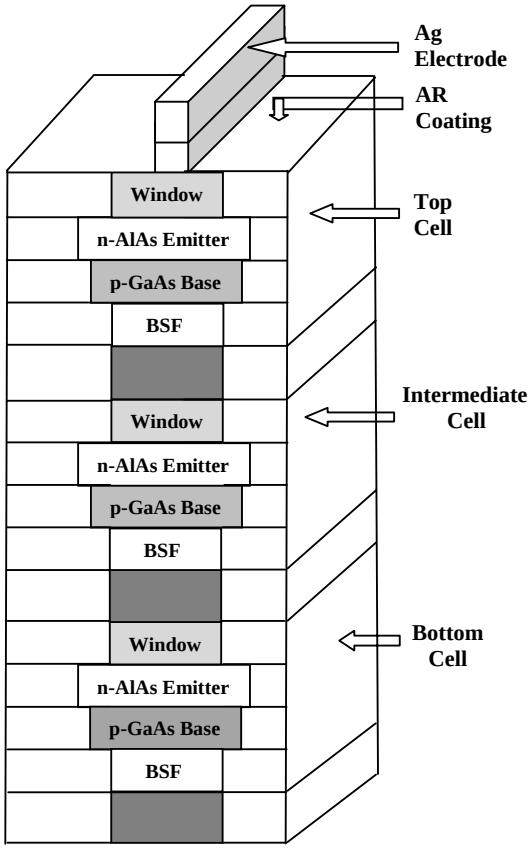

Fig. 1 : Schematic illustration of the proposed lattice matched solar cells.

III. Performance Analysis

The performance of solar cells depends on the choice of material used, the direction of light energy incident into the p-n junction, the number of junctions between the cells, the matching of the lattice of the used compound alloys, and carrier concentration. The amount of light energy absorbed by the p-n junction of solar cell is one of the important issues in performance evaluation. The less the reflection of incident light, the more efficient the solar cell is. The values of different parameters for the materials of Ge, GaAs, and AlAs which are used in the theoretical design and performance evaluation of the lattice matched multifunction solar cells are shown in Table I.

Fig. 2 shows the graphical representation of reflectance or reflection coefficient and efficiency of lattice matched AlAs/GaAs/Ge-based MJ solar cells. Efficiency of the solar cells decreases with the increasing percentage of reflectance.

The current densities for electrons and holes are expressed as [7],

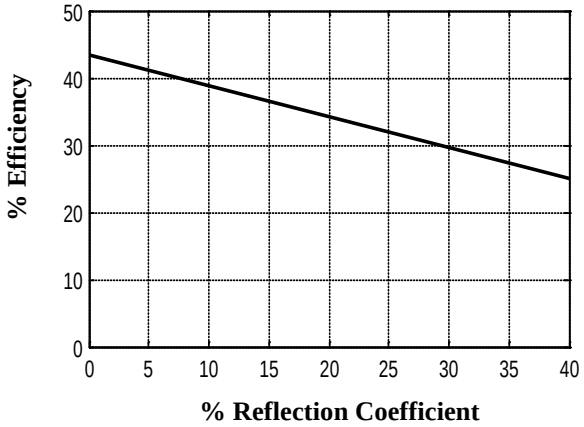

Fig. 2 : Efficiency variation of solar cell with respect to reflection coefficient.

$$J_n = q\mu_n n_p \xi + qD_n \frac{dn_p}{dx'} \quad (1)$$

and

$$J_P = q\mu_P p_n \xi - qD_p \frac{dp_n}{dx'} \quad (2)$$

where q is the electron charge, μ_n and μ_p are the mobility of electrons and holes respectively, p is the electron concentration in p region, p_n is hole concentration in n region, ξ is electric field, and $D_{n,p}$ is the minority carrier diffusion coefficients in n and p regions respectively.

In the case of an n on p junction with an n-type emitter and p-type base the expression for p on the top side of the junction is given by

$$D_P \frac{d^2 p_n}{dx'^2} + \alpha F(1-R)e^{-\alpha x'} - \frac{p_n - p_{no}}{\tau_p} = 0 \quad (3)$$

where F is the number of incident photon per cm^2 per second per unit band width, α is the absorption coefficient, R is the number of reflected photon from surface, p_{n0} is the equilibrium minority carrier density in the dark, and τ_p is the minority carrier lifetime.

The Open circuit voltage is expressed as [8],

$$V_{oc} = \frac{kT}{q} \ln\left(\frac{J_{sc}}{J_0} + 1\right) \quad (4)$$

and

$$J_0 = qn_i^2 \left(\frac{D_{nj}}{L_{nj} N_A} + \frac{D_{Pj}}{L_{Pj} N_D} \right), j = 1,2,3....n \quad (5)$$

where J_{sc} is the short circuit current density, J_0 dark saturation current density, n_i be the intrinsic carrier concentration, N_A and N_D are the acceptor and

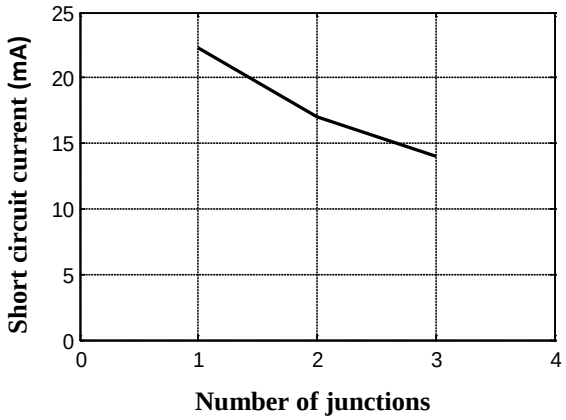

Fig. 3 : Variation of shot circuit current with number of junctions.

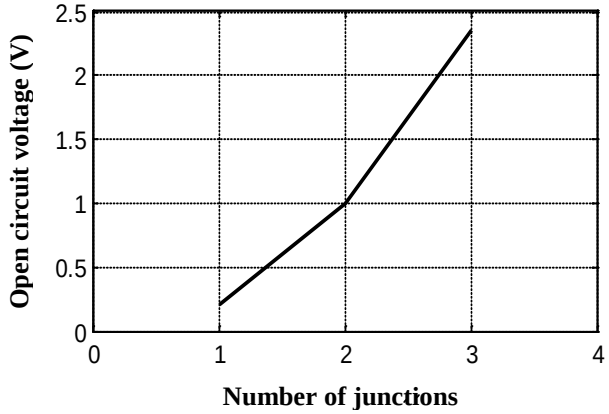

Fig. 4 : Variation of open circuit voltage with number of junctions.

Donor impurities respectively, and $L_{n,p}$ is minority carrier diffusion length in p and n regions respectively.

Short circuit current decreases as the number of junction increases. Simulation result shows that with the increase of number of junctions from single to triple short circuit current decreases about 35%. The result is shown in Fig. 3.

Fig. 4 shows the variation of open circuit voltage with the number of junctions. Open circuit voltage increases with increasing the number of junctions. For choosing of a new junction material, care has been taken about lattice constant so that lattice mismatch does not create in designing of MJ solar cells.

As the number of junctions i.e. the number of cells increases, short circuit current decreases and open circuit voltage increases which consequently causes the increase of solar cell efficiency. Fig. 5 shows the variation of efficiency with the number of junctions. Simulation result shows that efficiency increases about 30% as the junction number increases from single to triple.

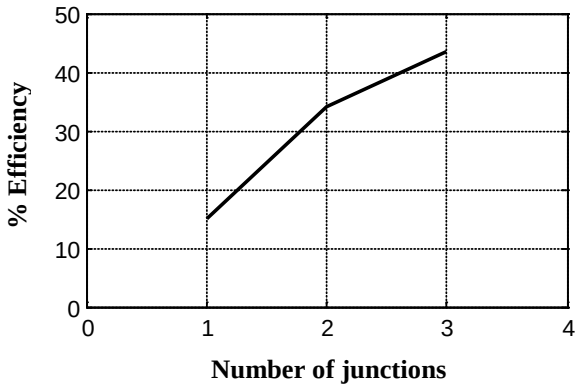

Fig. 5 : Efficiency variation of solar cell with respect to number of Junction.

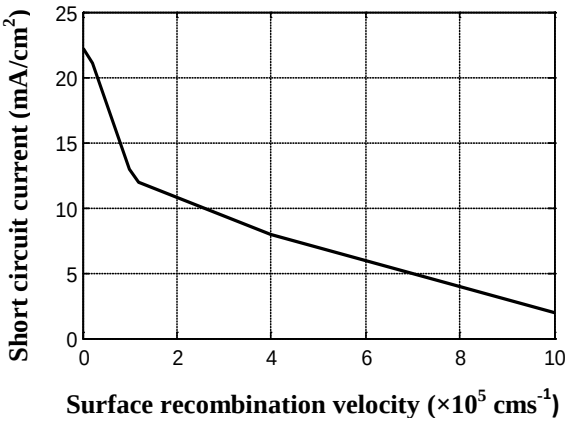

Fig.6. Effect of surface recombination velocity on short circuit current

The influence of surface recombination velocity on the short circuit current is shown in Fig. 6. Higher the recombination velocity, lower the short circuit current. Lattice matched solar cells reduce short circuit current (Fig. 3) which in turn increase the efficiency of the solar cells.

The comparison between lattice matched and mismatched triple junction solar cells considering the values of open circuit voltage, short circuit current, and efficiency is shown in Table II.

Table I: The Simulation Results of Lattice Matched MJ Solar Cells

Parameters	Ge	GaAs	AlAs
N_A (cm^{-3})	10^{16}	10^{16}	10^{16}
N_D (cm^{-3})	10^{18}	10^{18}	10^{18}
n_i (cm^{-3})	2.33×10^{13}	1.84×10^{6}	$8{\cdot}5\times10^{17}$
N_C (cm^{-3})	1.04×10^{19}	6.0×10^{18}	1.2×10^{19}
N_V (cm^{-3})	4.45×10^{19}	7.72×10^{18}	4.62×10^{19}
J_o (A)	7.2×10^{-3}	1.1×10	8.9×10^{-5}
V_{oc}(V)	0.20	0.7928	1.33
V_T(V)	2.3228		

Table II: Comparison Table Between Lattice Matched and Mismatched Triple Junction Solar Cells

Parameters	Lattice matched (AlAs/GaAs/Ge)	Lattice mismatched (AlAs/GaAs/Ge)
Open circuit voltage, V_{oc} (V)	2.3228	2.683
Short circuit current J_{sc} (mA/cm_2)	22	15.94
Efficiency (η)	43.5%	37.73%

IV. Conclusions

The theoretical design of the lattice matched AlAs/GaAs/Ge-based multi junction solar cells has been proposed and performances have been evaluated. The performances are evaluated by developing a simulation model which optimizes the design of the lattice matched AlAs/GaAs/Ge MJ solar cells for high efficiency. The efficiency of the proposed device structure has been obtained to be ~ 43.5%. The lattice mismatch is made to about nil. This increases surface recombination velocity and decreases short circuit current. The currents of each junction are made equal by adjusting the thickness of the emitter. Some major challenges including tunnel junction, buffer layer, and anti reflection coating in designing the effective MJ solar cells have been overcome. All these results show that the proposed AlAs/GaAs/Ge based multijunction solar cells are promising candidates to achieve high efficiency.

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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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