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VOLUME 12 NO. 2 JULY – DECEMBER, 2013

EMERGENCE OF NEW ERA FOR REINFORCED BAKED CLAY CONSTRUCTION

Allah Bux Memon* Nadeem-ul-Karim Bhatti** Abdul Aziz Ansari***

ABSTRACT

Persistent pursuit for cheaper and reasonably durable buildings led to the construction of relatively new form of erection of pre-cast buildings consisting of pre-perforated post-reinforced baked clay panels of structural members. These panels are reinforced after baking with the help of grouting by using cement slurry. Although the uses of baked and sundried bricks have remained in use for construction of buildings since immemorial times; the concept of baked clay beams, column and slabs is new one. In this paper the authors present the details of systematic research which has been carried out to prove that if pre-perforated post-reinforced baked clay beams are employed for pre-cast construction, the economy could be achieved by up to 30% without sacrificing strength, durability and stability of construction. This is particularly important because of high rate of inflation and ever increasing cost of construction. Full details of this mode of construction are presented in the following section.

1. INTRODUCTION

Clay is a local material which are extensively used in construction of cob and adobe houses in Pakistan and across the Globe; however, no attempt had previously been made to determine quantitatively their fundamental structural / strength properties and material constants of it and therefore, no much information is available in the technical literature. The local skilled masons used their proportions only on the basis of experience and intuition.

Apart from that a variety of waste materials were just thrown away instead of trying to find their use as major ingredient in construction work. Therefore a systematic study was carried out on local clay to be used as construction material and subsequently results were presented.

The authors conducted a number of studies on the mechanical properties of clay in the past [1-14] which in turn suggest that by no means clay is an inferior material for construction; however, it has gone through negligence in the research community and could not receive proper attention.

In order to reduce the cost of construction and make use of materials locally available, the over-escalating cost of construction materials such as reinforcement steel, cement, coarse aggregate of hill origin, led to the idea of using local materials which are relatively cheaper but can successfully be used without sacrificing the quality of the work.

Pre-stressed baked clay blocks were prepared with an approach to enable them with an improved tensile performance [12-14].

2. AIMS AND OBJECTIVES OF PRESENT STUDY

The main objective of this research investigation is to manufacture and study the behaviour and properties of pre-perforated post - reinforced baked clay panels of beams. To achieve the above mentioned aim the related objectives associated are identifies as follows.

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(i) To develop RBC as replacement of RCC as chief material of construction for multistory buildings.

(ii) To check the suitability of baked clay structural panels for construction of multistory buildings without sacrificing the strength & durability of buildings.

(iii) To achieve the strength of this material at a reasonable level with concrete by applying various levels of pre-compression.

(iv) To achieve economy by applying

  (a) Very cheap local materials i.e. clay and pit-sand.

  (b) Saving in terms of cost of transportation of heavy materials over long distance.

  (c) Minimization of expenditure for finishing like plastering or applying paints and distempers etc with proper and uniform burning giving it a naturally good appearance, colour and texture.

(v) Step towards the mechanized system (manufacture & developed of equipment in order to pave the way for;

  (a) Mechanized mass scale production of the panels of structural members with relatively lower cost of production under very controlled conditions emulating those of laboratory.

  (b) Quick and speedy erection of building by making use of pre-cast panels

3. MATERIALS, METHODOLOGY AND BAKING SYSTEM

3.1 MATERIALS

3.1.1 Clay and pit-sand

The clay was obtained from 25 different sources at a depth of 100mm (4 ft) from the ground level. It was dried at a temperature of 105 ^{O}C for 24 hours. Then all the samples were sent for chemical analysis to detect the presence and quantity of various salts. The clay was then pulverized and pit-sand was mixed with it. Initially the ratio of pit-sand was a variable to find the best composition.

3.1.2 Mixing Water

Potable water was mixed in the mixture of clay and pit sand to the extent of 18% to 20%. In fact samples of underground water from a large number of sites were tested for various properties and salts.

3.1.3 Cement slurry

Ordinary Portland Cement and fine hill sand passing through standard sieve No 16 were mixed in the ratio 1:1 and the slurry was produced by adding water five times the weight of cement. The process of making the holes is shown in Fig 1, while the slurry was forced in to the holes where steel bars had been housed as shown in Fig 2. The slurry was developed during this study based on experimentation in terms of proper flow, complete filling of the space in the holes and proper bond between steel and surrounding baked clay.

Fig. 1: The system to pullout the shaft placed to form holes for pre-perforation

Fig. 2: Grouting System

3.1.4 Reinforcement

Tor-steel bars of 9.53 mm (3/8 inch) diameter, 12.7 mm (½ inch) diameter and 15.87 mm (5/8 inch) diameter were used. In Pakistan for the sake of economy 74% of reinforcing steel bars is produced from scrap. The manu-facturing processes also vary considerably. There-fore, their strength properties are not uniform. These bars showed limited ductility. The batch of steel bars procured for our research did not show distinct yield point therefore the average 0.2% proof stress was calculated for these bars and was found to be 554.2 N/mm^2 (80360psi) and average ultimate stress was 652 N/mm^2 (94540 psi).

3.1.5 Concrete

Four concrete beams were cast, cured and tested for the sake of comparison of results. The concrete ingredients were mixed by weight for the characteristic strength of 20 N/mm^2 (3000 psi) at 28 days. The size of coarse aggregates was 10 mm (0.375inch). The value of slump was in the range of 10-30mm.

3.2 METHODOLOGY

Initially pH value, Electric Conductivity, Exchangeable Sodium and Gypsm, Total salts content in solution

(PPM), Moisture Contents, Specific Gravity, Liquid Limit, Plastic Limit, Density of wet and dry soil are to obtain from twenty five different sites is determined. Preliminary studies are performed in terms of shrinkage, specific gravity, compressive strength, tensile strength, Poisson's ratio and modulus of elasticity of baked clay specimens consisting of hundreds of specimens including cubes, cylinders and briquettes. The major parameter is clay and pit-sand ratio.

A large number of baked clay specimens is compacted by applying compacting force of 6 N/mm^2 to improve the structural properties. Substantial equipment and testing arrangements required are also fabricated. Stiff steel mould are fabricated for casting the models of beam panels.

The clay was obtained from various sources at a depth of 1220 mm (4 ft) from the ground level. It was dried at a temperature of 105 ^{O}C for 24 hours. The clay was then pulverized for micro-fining it. Then as per previous research conducted by the author [2] 30% of pit-sand, was mixed. Mixing of the materials and the water was done with the electrically operated Pan mixer. Mixing was done for approximately 10 minutes for each batch. After delivery of the material in the mould, compressive force was applied and measured with the help of electric load cells and digital display amplifier system. Compression was applied by tightening the wing nuts as shown in Fig 1. The compression force for compaction is the major factor to achieve required strength of baked clay. Several impediments and hurdles were experienced. For example enormous shrinkage occurred during drying which caused cracking of the beams rendering them useless. The drying under the shade without exposure to sunshine with a thin plastic wrapper solved the problem. Special scheme was resorted by providing a heavy wooden plank fitted with a very smooth surfaced metallic sheet properly oiled to support the beam specimen at the bottom during its drying period; so that shrinkage and consequent deformation (i.e. shortening of the beams) did not cause any cracking. However, a system of slight compression with the help of springs was also devised and used as shown in Fig 3.

Figure 3: Photograph of the system used to avoid the cracking in the clay beams due to shrinkage.

It must be mentioned here that the beams cast, dried, baked and tested during this experimental investigation were 150 mm (6 inches) wide 300 mm (12 inches) deep and 1950 mm (6.5 ft) long initially but were reduced in length by 100 mm (4 inches), breadth decreased by 7.2 mm (0.3 inches) while the depth showed a shrinkage of 14.3 mm (0.6 inches).

After drying for sufficient time under the shade the beams were exposed to sunshine to exclude as much moisture as possible which was trapped deep inside them. The beams were then placed in the Kiln where the temperature was measured with the help of Thermo-Couples. The temperature and time periods were selected after trying a large number of temperature and duration combinations to achieve the best possible results because the thickness of beams is obviously much more than bricks and therefore the complete baking of the beams could be possible only on the basis of experimental investigation. The beams were pre-perforated near the bottom with two holes of one inch diameter for placement of tensile reinforcement. However, a few beams were reinforced both at top and bottom hence there were two holes near top and two near the bottom in these beams. A few beams contained vertical holes at 6 inch centre to centre for shear reinforcement. The steel bars of 3/8", ½" and 5/8 inch diameter were used as longitudinal reinforcement. A puller was manufactured to pull out the steel shafts from the beams after their casting as shown in Fig 1. The bond between steel bars and the surrounding baked clay was achieved through forced grouting of cement slurry with fine aggregate in the ratio 1:1 as shown in Fig 2.

After grouting curing was done for 14 days as shown in Fig 4. This created sufficient bond to avoid the problem of slipping of bars up to the ultimate load.

Figure 4: The tube to cure the baked clay beam after grouting

3.3 BAKING SYSTEM

For baking the cubes, cylinders and beams during this experimental work, a kiln as shown in Fig. 5 & 6, was constructed. The kiln was heated by burning fire wood.

Fig. 5: Photograph showing the Isometric view of the kiln

Fig. 6: Photograph showing back view of the kiln

Each time for complete cycle of burning, approximately 800 to 900 kg of fire wood is consumed. The temperature was controlled and maintained carefully. Initially the lower temperature of 250°C was maintained for six hours. The temperature was then raised gradually to 950 °C and was maintained at this level for 16 hours. Then the temperature was lowered slowly and the fire was stopped and the kiln was allowed to cool down over next two days. The inner space of the kiln was enough to burn six beams at a time. The beams were placed inside through rectangular opening on the opposite side of the burning wood. There is an opening at the top which is covered at the time of burning. The cover itself is made up of clay. After the burning is over, the cover is partly removed for gradual cooling of the baked items. The temperature was maintained and measured with the help of thermo-couple. Four flues were provided opposite to each other to create draught.

4. EQUIPMENTS & MACHINERY

Since the use of reinforced baked clay panels was a new idea. It was not possible to find standard equipment and machinery in the market. This is invention of new gadgets which are not available in the market and lot of thinking and experimentation has gone in to it. First of all, the requirements were assessed.

Then ideas were conceived, strategy was devised, systems were envisaged, appropriate design was accomplished, bits and pieces were procured and in the end the required equipment and machinery were fabricated. They were used experimentally. Their behaviour was studied carefully and after satisfactory performance they were employed for the actual project. Two years' hard work along with considerable expenditure has been labeled as fabrication. Therefore these equipment and machinery were designed according to the design specifications. The details of the sample preparation and testing procedure are given in Ansari A. A. 2007 [5].

5. PRE-TENSIONING AND POST-TENSIONING

In pre tensioning, high tensile wires and strands are stretched to the required tension and anchored to bulk-heads. Photograph showing the system of baked clay pre-compression in Fig 7 & 8, testing process of pre-compression baked clay beam in Fig 9 and cracking pattern of pre-compression baked clay beam in fig 10. The tendons that are used for pre-tensioning and post-tensioning may consist of high tensile wires. The wire may be plain, crimped or dented. In both pre-tensioning and post-tensioning, the tendons need to be stretched to the required tension.

Fig. 7: System for applying pre compression to increase the strength of baked clay beams

Fig. 8: A bulkhead system fabricated for pre compression

Fig. 9: Pre-compression baked clay beam is testing on Torsee Testing Machine

Fig. 10: Photographs showing the cracks after testing the beam

6. DEVELOPMENT OF EXPERIMENTAL SET-UP

Torsee Testing Machine was used to test the beams. Load cells were used together with digital display system to measure intensity of the load independently. Demec Gauge was used to measure the strain at various locations with reference to the neutral axis. Thirteen pairs of demec pads were stuck on the beam to measure the strain with the help of demec gauge. To test the fundamental structural properties of the beam material itself specimens were cut from the intact portions of beams after testing. The flexural strength of all the beams in terms of steel and baked clay was estimated by using the recommendations of BS CP-8110 [15] and ACI-318 [16] after removal of partial safety factors. The shear strength was also estimated. This experimental study was carried out with the intention to develop design criteria for baked clay buildings and other types of structures by using clay as the chief material.

However, it must be mentioned here that the failure was not caused by the exhaustion of the strength in any terms but due to failure of the system which was designed to apply pre-compression. Actually not only the threads on the steel bars yielded but even the additional constraint provided by the welding also failed. Several different ways and means were adopted to strengthen the junction at both the ends of the beams.

The intensity of the load was measured by using the “Proving Ring’. It is surprising to note that failure occurred when the design load of the end support connections was not even reached.

Here we are more concerned about the difficulties faced to provide shear reinforcement. Hence ways and means must be devised to eliminate the use of reinforcement as far as possible. The longitudinal reinforcement can always be accommodated after the structural sections are moulded, dried and baked by inserting the steel and then by grouting to accomplish the bonding but the shear reinforcement is hard to be accommodated after baking. Under these circumstances the only options left for us is to avoid any reinforcement except longitudinal one and this can best be achieved if we strengthen the structural members to an extent that any failure which is sudden, brittle and without impending warning. Therefore the baked clay must be pre-compressed to a level that there could not be any tensile stresses to produce cracking or causing a diagonal failure [14]. With these motives in the sight the work has been under taken the details of which is presented in this paper.

7. DISCUSSIONS

The ultimate stage in terms of flexural or shear could not be reached because of the premature destruction of the anchorage, the failure loads exceeded from those which were attained in case of un-pre-compressed systems. Experimentally it has been proved that the shear strength could be increased from 5 to 50 percent if pre-compression is applied [17]. This was expected an increase which could comfortably be had in the building when they are constructed using baked clay without vertical reinforcement. The other purpose was to seek the possibility of using the baked clay for pre-stressed construction. When rectangular beams simply supported on rollers were tested by applying a point load the maximum benefit which could be achieved in terms of shear strength is of the order of 9 % (Table 1).

However, when UDL was applied this figure touched a

TABLE 1: EFFECT OF INTENSITY OF PRE-COMPRESSION FOR VARIOUS TYPES OF BEAMS

Description	RECTANGULAR SECTION											
	POINT LOAD						UNIFORMLY DISTRIBUTED LOAD					
	CP-8110			ACI			CP-8110			ACI		
	BCRRP	BCRRPPC	%age Diff.	BCRRP	BCRRPPC	%age Diff.	BCRRUD	BCRRUDPC	%age diff.	BCRRUD	BCRRUDPC	%age diff.
Flexural Strength (British steel)	89688	94103	4.7	101198	103766	2.47	92402	146467	36.91	101543	160458	36.7
Flexural Strength (Pak steel)	94530	103586	8.7	106469	109906	3.13	99613	160244	37.8	107777	170043	36.6
Flexural Strength (Baked Clay)	128312	159565	19.5	103128	105827	2.56	193145	252796	23.5	158349	106163	32.9
Shear Strength Calculated	38977	21261	20	27086	29833	9.21	30373	20832	14.14	26816	30248	11.34
Experimental load.	56595	63495	10.8	56595	62575	9.56	114095	115015	0.79	114279	115237	0.83
Exp.shear strength Cal. Shear strength	0.71	1.46	8.9	1.04	1.05	0.95	1.88	3.70	13.78	2.12	1.91	9.90
Experimental Displacement	8.4	7.7	9	8.4	7.7	8.33	9.7	8.12	16.3	9.8	8.12	17.14
Strain at the Level of steel	1700	1300	23.5	1700	1300	23.5	2300	1800	21.7	2300	1800	21.74
Level of stress from measured strain	226	490	53	226	419	53..9	611	491	19.6	611	492	19..47

BCRRP : Roller supported rectangular subjected to point load at center.

BCRRPPC : With proving ring without grouting, roller supported rectangular subjected to point load at center.

BCRRUD : Roller supported rectangular subjected to uniformly distributed load.

BCRRUDPC : With providing ring without grouting, roller supported rectangular subjected to uniformly distributed load.

Note: All the values are expressed in N/mm^2.

level of approximately 14 %. As usual the displacement maintained its lowest level with maximum value of 9.7mm. This is only 3.4 % of the depth of the beams. A ductile failure is needed rather than sudden due to crushing of baked clay or the diagonal failure. Therefore we tried to discover the best solution for resisting any brittle failure which must be avoided in all circumstances. Table 2, gives the details of experimental load at failure, experimental strain at the level of steel in baked clay, maximum experimental strain in compression zone and

TABLE 2: VARIOUS EXPERIMENTAL DATA OF BEAMS TESTED FOR DIFFERENT COMPRESSION FORCES

S#	Description	Exp. load at failure (N)	Exp: Strain at the level of steel	Experimental displacement mm	Experimental Max. strain in compression zone	Maximum Bending Moment (F.E)	REMARKS
1.	BCRRPPC-1	63020	0.0013	7.72	0.0021	229100	BCRRPC: With proving ring without grouting, Roller supported rectangular subjected to point load at centre BCRRUDPC With proving ring without grouting, Roller supported Rectangular subjected to UDL BCRRPPCG$_{20}$: With 20 kN pre-compression force BCRRPPCG$_{30}$: With 30 kN Pre-compression force
2.	BCRRPPC-2	61180	0.0012	7.68	0.0020	222300	
3.	BCRRUDPC-1	67620	0.0018	8.13	0.0023	160200	
4.	BCRRUDPC-2	68080	0.0018	8.11	0.0023	160267	
5.	BCRRPPCG$_{20}$-1	55200	0.0017	8.89	0.0023	198900	
6.	BCRRPPCG$_{20}$-2	54740	0.0017	8.64	0.0024	198900	
7.	BCRRPPCG$_{30}$-1	55200	0.0017	8.28	0.0024	198900	
8.	BCRRPPCG$_{30}$-2	55200	0.0017	8.94	0.0024	198900	

TABLE 3: COMPARATIVE STRENGTH ANALYSIS OF BAKED CLAY & CONCRETE

S #	Boundary conditions	Flexural strength (steel)						Flexural strength (concrete)						Shear strength (calculated)					
		CP8110		% age	ACI		% age	CP8110		% age	ACI		% age	CP8110		% age	ACI		% age
		Baked clay N	Conc-rete N		Baked clay N	Conc-rete N		Baked clay N	Conc-rete N		Baked clay N	Conc-rete N		Baked clay N	Conc-rete N		Baked clay N	Conc-rete N	
1	Roller (Single reinforcement)	106034	118166	10	113402	125991	9.9	246856	256860	3.9	163220	188234	13	16539	18304	9.6	30103	31230	3.6
2	Roller (double reinforcement)	117929	119524	1.3	126119	126962	0.6	240916	286160	15	174251	190848	9	16907	18304	7.6	29563	33540	11
3	Fixed (double reinforcement)	202064	203362	0.6	216977	217846	0.4	238275	260320	8.4	192720	198309	2.8	16874	18304	7.8	29529	32887	10.2
4	Fixed (double reinforcement)	205913	201025	2.3	220549	217649	1.3	237376	256816	7.5	192862	195056	3.3	16982	18304	7.2	29874	32743	11.4
Average				**3.5**			**3.05**			**8.7**			**7.02**			**8.5**			**9.05**

experimental displacement of the beams subjected to pre-compression of 20 as well as 30 kN pre-compression force. Here it can be seen that maximum strain in baked clay never exceeded the limit of 2400 micro-strain which is a clear manifestation that flexural limit was not crossed; rather everything was within the safe limit.

Otherwise properties studied so far allude to the conclusion that this material holds the promise for future; if properly handled and properly designed. Therefore, it can be safely concluded that such an application of pre-compression would hopefully show a drastic beneficial effect if only the anchorage systems are fully operative. It must be mentioned here that for the sake of comparison four concrete beams were also cast and tested. Table 3, shows the comparative analysis of strength of baked clay and concrete. The percentage difference of experimental displacement of concrete is somewhat higher than that of baked clay. Averagely the displacement of concrete beam is 27 % higher than the baked clay. Therefore it can safely be deduced that lesser the displacement, lesser shall be the cracking and ultimately behaviour of baked clay could be regarded as more favourable than concrete.

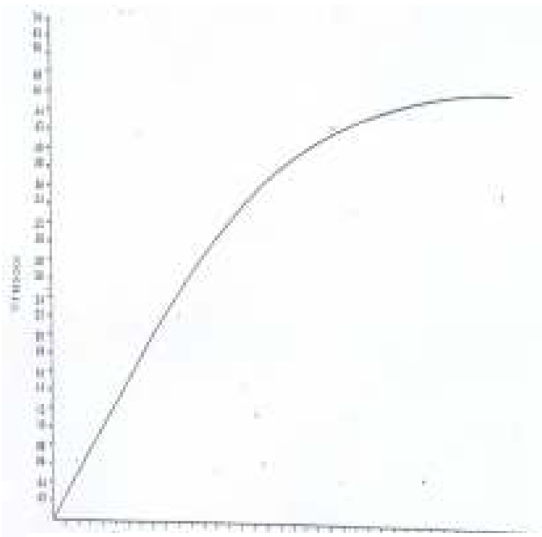

Figure 11: Graph showing the stress-strain relationship of baked clay beam.

Results are satisfactory we are to find that baked clay is not an inferior material than concrete. Depending upon the boundary conditions, estimated flexural strength in terms of steel and concrete together with two estimations on the basis of BS CP-8110 [15] and ACI-318 [16], results are presented in Table 3.

It is apparent that the difference is only of the order of 0.6 to 10 % and 0.4 to 9.9% and to 8.4 to 3.9% and to 2.8 to 13 % finally 10.2 to 11%. This all can be regarded as negligible. Therefore, it can safely be concluded that baked clay is equally good if not better than concrete.

The strain in baked clay beams at the level of steel in tensile zone just one stage before failure has been converted into stress by using the Fig. 11. The figure is based on the behaviour of baked clay specimens subjected to direct axial compressive stress tested in the laboratory. This level of stress is so high that micro-cracking invisible by naked eye must have occurred. However, this could not be detected.

8. CONCLUSIONS

1. Experimentally it has been proved that the shear strength could be increased from 5 to 50 percent if pre-compression is applied.
2. Here it can be seen that maximum strain in baked clay never exceeded the limit of 2400 micro-strain which is a clear manifestation that flexural limit was not crossed; rather everything was within the safe limit.
3. Pre-compression would hopefully show a drastic beneficial effect if only the anchorage systems are fully operative.
4. The percentage difference of experimental displacement of concrete is somewhat higher than that of baked clay. Therefore it can safely be deduced that lesser the displacement, lesser shall be the cracking and ultimately behaviour of baked clay could be regarded as more favourable than concrete.
5. Pre-perforated and post-reinforced system of construction consisting of pre-cast panels of baked clay holds promise as an alternative of cement concrete at a reduced cost without compromising on the quality, durability and elegance of multistory buildings.

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LOCAL AND ADAPTIVE SELECTION OF OPTIMAL PARAMETERS FOR TV REGULARIZATION MODEL AND THE FEM BASED STEREO-VISION SIMULATION

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ABSTRACT

A nonlinear variational model is proposed for the simulations of one directional disparity map using FEM(finite element method) based numerical scheme for the given Total Variation (TV) stereo problem. Our main goal is to study the appropriate selection of local smoothness parameters chosen in a uniform way and their regularization effects on the disparity image with the triangular grids as computational domain.

Keywords: ***Disparity map, regularization, Adaptive finite elements, optimization.***

1. INTRODUCTION

The efficient numerical solution of partial differential equations (PDEs) plays an important role in the engineering problems. This demand and the ever increasing computational power from current computer hardware have brought the rapid development of numerical methods for partial differential equations, a development that encompasses convergence analysis and implementation aspects of software packages and programming languages like [16 (FreeFem++)]. In this presentation we consider the TV stereo model to estimate the disparity map from two consecutive frames of same stereo scene.

The estimation of one directional disparity maps from the same image scene is one of the classical problems of image analysis research but due to the ambiguities in camera settings and aperture problem this research task is still challenging for image practitioners. Once this one directional displacement is computed accurately then it is possible to measure the distance between camera and the object. This measurement has many possible applications in driver assistance systems and auto aircrafts without pilots.

As the TV and Perona-Malik regularizations are the most popular regularization approaches for computer vision problems especially for the image restoration and Image motion problems [1-6, 8, 9, 14, 15, 18-20] and variational stereo methods [7, 10, 11, 20].

It is observed from the available literature on PDEs based approaches in image processing and computer vision [6, 9, 10, and 16] that usually the practitioners use finite difference methods using rectangular grids for the PDEs based image processing. This work provides an efficient computational approach based on adaptive finite element method (FEM) using triangular grid.

2. TV STEREO MODEL

We consider the following TV stereo model to compute the disparity map u between the stereo image pair $I:\Omega\times\mathrm{R}\rightarrow\mathrm{R}$

$$E(u)=\int_{\Omega}(\alpha\ (\psi(|\nabla u|))+D(I(x),u))\,dx....(1)$$

where

$$\psi_{\beta}(|\nabla u|)=\sqrt{\beta^{2}+|\nabla u|^{2}}\ ....(2)$$

Is the smoothness part and the

$$D(I(x),u)=(I_{x_1}+I_{t})^{2}\ ....(3)$$

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Is called the data term which comes from the grey value constancy assumption

$$I(x+u,t+1)=I(x,t)\ldots\ldots(4)$$

We set $x=(x_1,x_2)^T\in\Omega$, here the two dimensional image domain is denoted as $\Omega\in\mathrm{R}^2$ and the terms I_{x_1}, I_t denote the derivatives with respect to x_1 and t respectively. α is strictly positive smoothness parameter.

For computation of disparity we use the energy minimization technique and we recall the following famous and basic result from the calculus of variations [6, 11]. The minimization of given two dimensional general energy functional

$$E(u)=\int_\Omega F(x_1,x_2,u,u_{x_1},u_{x_2})\,dx\ldots\ldots(5)$$

Satisfy the Euler's-Lagrange Equation

$$F_u-\partial_{x_1}F_{u\,x_1}-\partial_{x_2}F_{u\,x_2}=0$$

with natural boundary condition

$$\frac{\partial u}{\partial n}=0,\ on\ \partial\Omega$$

Where n is outward normal to the boundary $\partial\Omega$, applying this direct result from the calculus of variations the computation of u is obtained from the minimization of energy functional (1) which yields the associated Euler's-Lagrange equation given as

$$0=-\mathrm{div}\left(\frac{\alpha\nabla u}{\sqrt{\beta^2+|\nabla u|^2}}\right)+(I_{x_1}{}^2u+I_{x_1}I_t)\ in\ \Omega\ldots\ldots(6)$$

Where $\frac{\partial u}{\partial n}=0,\ on\ \partial\Omega$, β is very small smoothness parameter which is used to avoid the zero division in TV regularizer. The equation (6) is a steady state solution of the gradient system

$$\partial_t u=-\mathrm{div}\left(\frac{\alpha\nabla u}{\sqrt{\beta^2+|\nabla u|^2}}\right)+(I_{x_1}{}^2u+I_{x_1}I_t)\ldots\ldots(7)$$

$\partial_t u$ denotes the partial derivative of u with respect to t. Variational formula for (7) can be derived as

$$(\frac{\partial u}{\partial t},v)+b(u,v)=l(f,v)\ldots\ldots(8)$$

Where we set $f=-I_{x_1}I_t$, one is therefore interested to compute $u\in H^1(\Omega)$ where

$$\begin{cases} b(u,v)=\int_\Omega\left(\frac{\alpha\nabla u\cdot\nabla v}{\sqrt{\beta^2+|\nabla u|^2}}\right)dx+\int_\Omega I_{x_1}{}^2u\cdot v\ dx \\ l(u,v)=\int_\Omega f\cdot v\ dx\ \ \forall\ v\in H^1\subseteq X\ldots\ldots(9)\end{cases}$$

H^1 is a Sobolev space which is defined as

$$H^1(\Omega)=\left\{u\in L^2(\Omega):\nabla u\in(L^2(\Omega))^2\right\}$$

For further details about Sobolev spaces and specifically $L^2(\Omega)$ spaces and their corresponding norms we refer the reader to review the basic theory of finite elements and Sobolev spaces in [12, 13].

3. FEM BASED NUMERICAL SCHEME:

We numerically solve the problem equation (8) on the following

Discrete space

$$X_h:=\left\{v_h\in C^0(\overline{\Omega})\Big|\ \forall K\in T_h,\ v_h\big|_K\in P_1(K)\right\}$$

Here $X_h\subset X$ is the discrete space with P_1 finite elements. C^0 is the space of continuous functions. The computational domain is considered as a triangular grid T_h with maximum size of each element $h>0$. Where $P_1(K)$ denotes the space of all polynomials functions having degree equal to one. To solve the week problem (8) on discrete space X_h the following implicit approximating scheme is proposed which is designed using both FEM (Finite Element method) and FDM (Finite difference method). The time derivative is discretized using forward difference operator.

$$(I+\tau A_\alpha)U^{K+1}=U^K+\tau L\ldots\ldots(10)$$

Where

$$U=[u_1,u_2,\ldots,u_N]\ldots\ldots(11)$$

The $u_1,u_2,\ldots,u_N$ are the smoothed disparity map grey values corresponding to the N number of nodes on triangular grid. The vector L is obtained from $l(f,v)$.

As the given bilinear form in equation (9) is symmetric and positive definite. The given implicit numerical scheme is unconditionally stable.

4. NUMERICAL RESULTS AND DISCUSSION

We consider a famous example of stereo pair Pentagon. The aerial view of Pentagon stereo pair with gray value images were downloaded from http:/vasc.ri.cmu.edu/idb/. Our goal is to check the disparity map for different uniformly selected values of smoothing parameter α specifically for the given FEM based numerical scheme. The value of small contrast parameter β is kept fixed for all experiments as $\beta = 0.00005$. Table1 & and Figure.1 show the Plot for the average disparity values for various choices of α. From the Figure .1 it is observed that the values of disparity map intensity slightly increases as we decrease the values of smoothness parameter α. The image results for the computed disparity maps on various fixed values of α are shown in the Figure2.(a-n). As the value of α is decreased, the grid is refined almost everywhere on the domain. We observe that some blurring effects appear in the computed disparity map with very small values of α, consequently, some useful information from the disparity map images become disappear. From overall performance of this particular numerical scheme, we have observed that with good visual quality disparity results were found when $0.5 \le \alpha < 1$. As these variational methods have some drawback from the computational point of view in the sense that they create some computational ambiguities in the disparity map estimation at all pixels of disparity image. Keeping this all in view we propose some reliable regularization estimates and a novel regularization approach which is based on the a posteriori estimates and an intelligent algorithm which automatically identifies the damaged regions of the disparity image and regularizes. Such type of the intelligent regularization control for this problem will appear in our forth coming papers.

5. CONCLUSION

Study of locally adaptive selection of smoothness parameters is given in this paper for the disparity map estimation from successful implementation of the variational model (1) using the Finite element method on the triangular grid as domain of computation. The observed results are given in table.1, Figure.1 and the obtained disparity map images are given in Figure. 2 (a-n). From overall performance of this particular numerical scheme, we have observed that with good visual quality disparity map results were found when $0.5 \le \alpha < 1$.

Table 1.Average disparity values for various values of α

alpha	Average Disparity
1000	0.0823566
500	0.109637
200	0.146255
100	0.17477
50	0.20208
20	0.23333
5	0.265949
0.9	0.291454
0.5	0.3006
0.1	0.348697
0.01	0.527864
0.001	0.859375

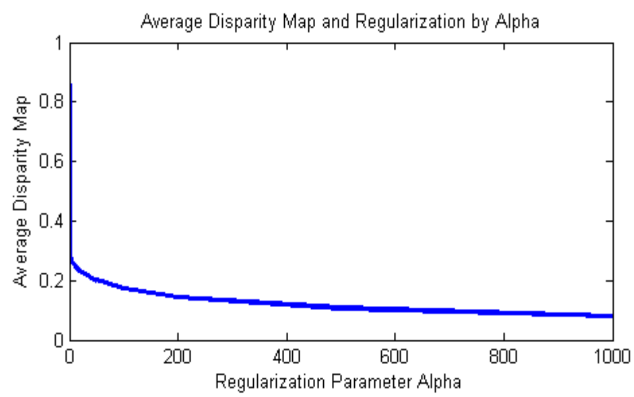
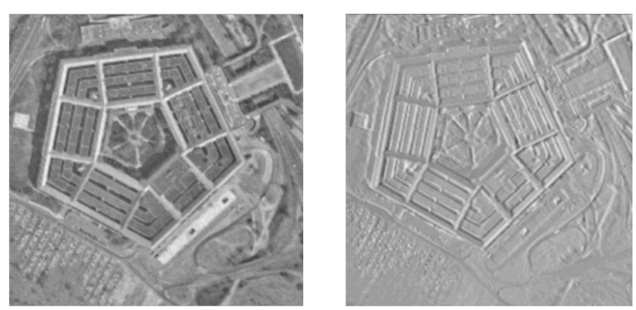
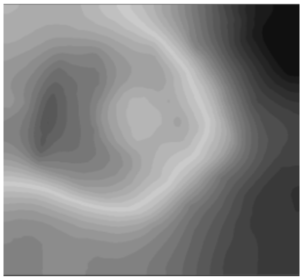


Figure 1. The plot of Average Disparity map for chosen local smoothness parameters.

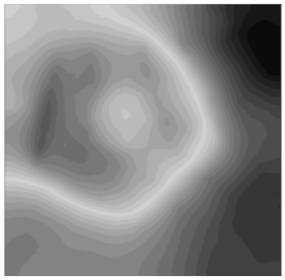


(a) Left Image Pentagon Stereo Pair

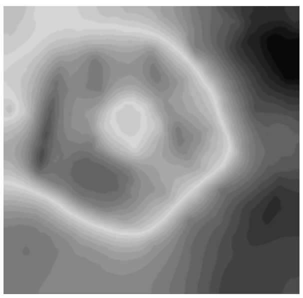
(b) Time Derivative (f_1,f_2)



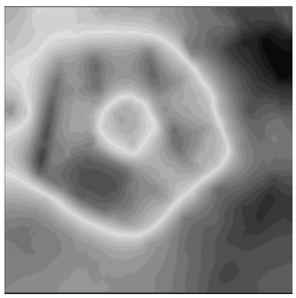
(c) Stereo Depth at $\alpha = 1000$



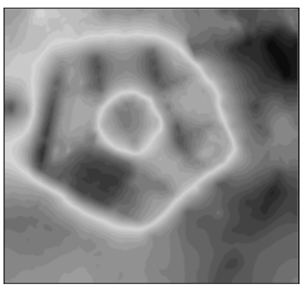
(d) Stereo Depth at $\alpha = 500$



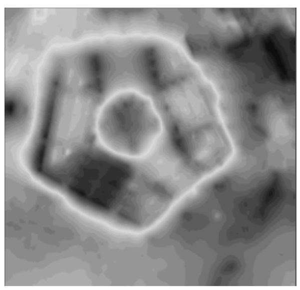
(e) Stereo Depth at $\alpha = 200$



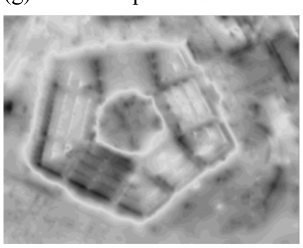
(f) Stereo Depth at $\alpha = 100$



(g) Stereo Depth at $\alpha = 50$



(h) Stereo Depth at $\alpha = 20$

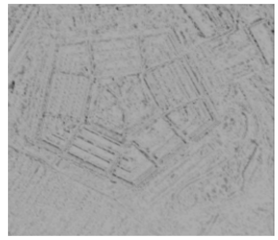


(i) Stereo Depth at $\alpha = 5$

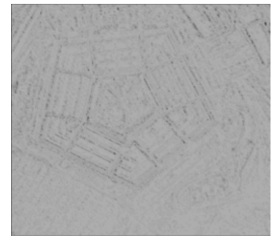
(j) Stereo Depth at $\alpha = 0.9$

(k) Stereo Depth at $\alpha = 0.5$

(l) Stereo Depth at $\alpha = 0.1$



(m) Stereo Depth at $\alpha = 0.01$



(n) Stereo Depth at $\alpha = 0.001$

Figure 2. Computed Disparity map results for various choices of the regularization parameter α .

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MULTILAYER PERCEPTRON FEEDFORWARD NEURAL NETWORK BASED POWER SYSTEM STABILIZER FOR EXCITATION CONTROL SYSTEM

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ABSTRACT

Electrical power system (EPS) is becoming more complex and non-linear due to its varying operating conditions. In order to keep EPS in the steady state condition, active power (P) or terminal voltage (V_t) and reactive power (Q) or frequency (f) must be controlled and maintained continuously. The response of the transient stability (terminal voltage) can be improved by adopting suitable controller as an additional voltage controller with the automatic voltage regulator (AVR) in the excitation system, whereas the dynamic stability (frequency deviations i.e $\Delta\omega$) can be enhanced with governing system. In power system networks, low frequency oscillations have become a major concern for many years. In order to depress low frequency oscillation, the power system stabilizer (PSS) parameters must be adjusted when there are changes in power system network conditions. This paper presents the application of multilayer perceptron feedforward neural network (MLPFFNN) as a controller to tune PSS parameters for achieving better enhancement in stability. For training MLP neural network, real power (P) and reactive power (Q) of synchronous machine are chosen as the input signals and the output are; the desired power network stabilizer parameters. The proposed controller is implemented as single machine connected at infinite bus (SMIB) and compared with conventional controllers using Matlab/Simulink. The results obtained show the promising results due to the improvement in terminal voltage (V_t) as well as frequency deviation ($\Delta\omega$).

Keywords: ***Synchronous generator, Power system stabilizer, Feedforward neural networks, Multilayer perceptron, Transient and dynamic stability, Matlab/simulink.***

1. INTRODUCTION

The control of active power and reactive power is very important to maintain the system in steady state condition [1]. The excitation system of the synchronous generator with automatic voltage regulator (AVR) controls the generated electromotive force (emf) and therefore maintains not only the reactive power flow but the power factor and current magnitude as well. The governor together with load frequency control (LFC) regulates the frequency of the generator and maintains the real power [2-8].

The power network is always complex and nonlinear due to continuously variation of loading conditions and is being subjected to small perturbations. The modern fast acting, high gain automatic voltage regulators (AVR) cause the poor oscillations or damping characteristics which deviate the rotor angle of the generator (δ).

These high gain AVRs cause a large phase lag at low system frequencies which are greater than the excitation system frequency. Therefore AVR has an important effect of minimizing synchronizing torque during sudden disturbances but it affects the damping torque negatively [3-8].

In power system networks, damping torque or low

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frequency oscillations become a major concern for many years. To offset this effect and to improve the system damping in general, a new signal producing torques in phase with the rotor speed are introduced. This supplementary stabilizing signal is known as "Power System Stabilizer (PSS)" of network. In order to depress low frequency oscillation, the power system stabilizer parameters must be adjusted when there are changes in power network conditions.

Various techniques of PSS parameters based on optimal variable structure control (OVSC), adaptive control (AC), and intelligent controls have been proposed to design PSS [9-15]. The artificial intelligent (AI) methods such as genetic algorithm G.A), simulated Annealing, Tabu Search, evolutionary programming and multi agent particle swarm optimization (MAPSO) for obtaining PSS parameters [16-20], self-tuning PSS [21], PI, PID, and Fuzzy based PSS [22-24], and Fuzzy set and NNs [25] are also suggested in literature.

These conventional power system stabilizers possess fix parameters and operate at particular loading conditions. These PSSs need tuning in case of changing loading conditions. The main limitation of such PSS is that it takes a large amount of computing time for on-line parameter identification and also need knowledge based, and membership functions which are defined off-line, and kept unchanged during the online operation.

For this problem, we need a power system stabilizer, which should possess self-learning, adaptation, approximation and artificial intelligence properties of handling the changes and uncertainties in the system in on and off-lines.

The neural network (NN) possesses great prospective capabilities because they have been developed on logical mathematical formulation and versatile and well-known mathematical back grounds [26].

Due to these problems an artificial neural network based PSS is proposed by taking angular frequency as an input to improve the transient and dynamic stability of electrical power system.

Feedforward multilayer perceptron (MLP) neural network with back propagation (BP) algorithms based PSS is proposed in this paper. The simulations results using Matlab/Simulink and neural network toolbox are compared with conventional, PID and proposed PSS. The applicability and suitability of the proposed PSS are investigated and the improvements in transient & steady state stability enhancement are discussed in detail.

2. MODEL OF A POWER SYSTEM

For the improvement of dynamic stability of an interconnected power system, a single synchronous generator connected to an infinite bus (SMIB) system is taken into consideration. The synchronous generator connected to a bulk network of a transmission line can be represented as Thevenin's equivalent circuit with external impedance (R_e + jX_e) [1, 4-8]. Figure 1 shows the equivalent circuit of SMIB.

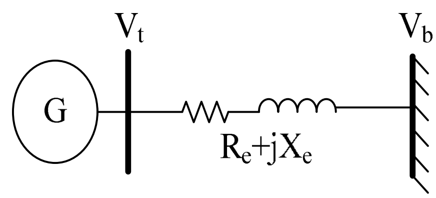

Figure 1: A single synchronous machine connected to an infinite bus (SMIB)

A simple linearized model of synchronous generator and excitation system is developed based on the linear model. The linearized equations for the synchronous machine are given by (the Δ subscripts are dropped for convenience) [1].

$$E'_{q\Delta} = \frac{K_3 E_{FD\Delta}}{1 + K_3 \tau'_{d0} s} - \frac{K_3 K_4 \delta_\Delta}{1 + K_3 \tau'_{d0} s} \tag{1}$$

$$T_{e\Delta} = K_1 \delta_\Delta + K_2 E'_{q\Delta} \tag{2}$$

$$V_{t\Delta} = K_5 \delta_\Delta + K_6 E'_{q\Delta} \tag{3}$$

$$\dot{E}'_q = -\left(\frac{1}{K_3 \tau'_{d0}}\right) E'_q - \left(\frac{K_4}{\tau'_{d0}}\right)\delta + \left(\frac{1}{\tau'_{d0}}\right) E_{FD} \tag{4}$$

From the torque equation we have

$$\dot{\omega} = \frac{T_m}{\tau_j} - \left(\frac{K_1}{\tau_j}\right)\delta - \left(\frac{K_2}{\tau_j}\right) E'_q - \left(\frac{D}{\tau_j}\right)\omega \tag{5}$$

By the definition of ω_Δ

$$\dot{\delta} = \omega$$

The complete state-space model of the synchronous generator with excitation system is given by

$$
\begin{bmatrix} \dot{E}'_q \\ \dot{\omega} \\ \dot{\delta} \\ \dot{V}_1 \\ \dot{V}_3 \\ \dot{V}_R \\ \dot{E}_{FD} \end{bmatrix} = \begin{bmatrix} -\frac{1}{K_3\tau'_{d0}} & 0 & -\frac{K_4}{\tau'_{d0}} & 0 & 0 & 0 & \frac{1}{\tau'_{d0}} \\ -\frac{K_2}{\tau_j} & 0 & -\frac{K_1}{\tau_j} & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ \frac{K_6 K_R}{\tau_R} & 0 & \frac{K_5 K_R}{\tau_R} & -\frac{1}{\tau_R} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{\tau_F} & \frac{K_F}{\tau_F \tau_E} & -\frac{K_F(S'_E + K_E)}{\tau_F \tau_E} \\ 0 & 0 & 0 & -\frac{K_A}{\tau_A} & -\frac{K_A}{\tau_A} & -\frac{1}{\tau_A} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{\tau_E} & -\frac{(S'_E + K_E)}{\tau_E} \end{bmatrix} \begin{bmatrix} E'_q \\ \omega \\ \delta \\ V_1 \\ V_3 \\ V_R \\ E_{FD} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{T_m}{\tau_j} \\ 0 \\ 0 \\ 0 \\ \frac{K_A}{\tau_A} V_{REF} \\ 0 \end{bmatrix}
$$

The state space model is represented with the excitation system only with state variables given by [1]

$$
x^t = \begin{bmatrix} E'_q & \omega & \delta & V_1 & V_3 & V_R & E_{FD} \end{bmatrix} \quad (6)
$$

The V_{REF} and T_m are the driving functions by assuming that V_S is zero [1].

3. ARTIFICIAL NEURAL NETWORKS (ANNs)

An artificial neural network (ANN) is a computational structure that is inspired by a crude electronic model based on biological nervous system in the brain. A neuron can be compared to the human brain in two ways. First, the network gets the information from its surroundings through a training process. Second, the neural network stores the acquired information within inter-neuron connection strengths or synaptic weights [4-5], [7-8], [26].

A learning rule, also referred as a training algorithm of a neural network, is used for adapting the weights and biases of a neural network and for training the network to perform a particular task. The learning mechanism adapts the weights of the different architectures and hence leads to a modification in the strength of interconnection. The selection of type of learning depends upon the behavior in which the parameter changes take place. There are two broad categories of learning rules in a neural network i.e., supervised learning and unsupervised learning [7-8], [26-28].

3.1 MULTILAYER PERCEPTRON NEURAL NETWORK (MLPNN)

Multilayer feedforward network is a particular type of neural networks. It consists of a set of source nodes which forms the input layer, one or more hidden layers, and one output layer. The input signal is applied in a forward direction through the network, on a layer-by-layer basis as shown in figure 2.

Multilayer perceptron networks are applied successfully for solving some difficult and complex problems by training them in a supervised learning scheme with a highly popular back-propagation algorithm. The back-propagation algorithm is based on the error-correction learning rule [4-5], [7-8], [26-28].

A multilayer perceptron network contains one input layer, one or more hidden layers and one output layer. The input layer consists of input data of the network. The hidden layer consists of computational nodes known as hidden neurons. The hidden neurons perform function of the interaction between the external input and network output in an efficient manner and extraction of higher order statistics. The function of the source nodes, in input layer of network, is to supply the input signal to neurons in the second layer (1st hidden layer). The 2nd layer's output signals are applied as inputs to the third layer and so on. The set of output signals constitutes the overall response of network to the activation pattern supplied by source nodes in the input first layer [7-8], [26-28].

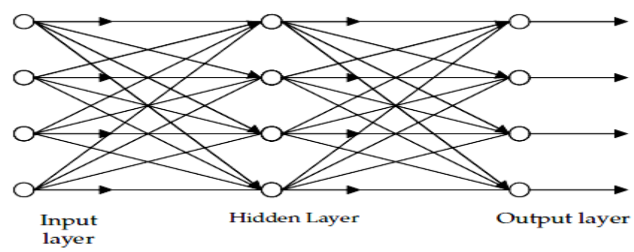

Figure 2: A multilayer feedforward neural network (MLPNN)

The back-propagation learning algorithm is applied for training multilayer perceptron (MLP) networks which is based on supervised learning. The algorithm is applied for adapting weights and biases of the neural network and reducing the error in its predictions on the training set [7-8], [26-28].

3.1.1 Levenberg-Marquardt Backpropagation

Levenberg-Marquardt is the fastest version of back-propagation algorithm. It is highly recommended as a favourite supervised algorithm, although it needs more memory than other algorithms [7-8]. The algorithm has been developed to approach second-order training speed without solving the Hessian matrix. For training feedforward networks the performance function takes the form of a sum of squares, therefore the Hessian matrix has been approximated as:

$$
H = J^T J \quad (7)
$$

The gradient can be solved as

$$g = J^T e \quad (8)$$

Where J refers to a Jacobian matrix consisting of first derivatives of the network errors with respect to the weights and biases, and e represents network vector errors. The Jacobian matrix can be easily solved through a standard BP technique which is simpler than the Hessian matrix.

The algorithm applies this approximation to the Hessian matrix as:

$$X_{j+1} = X_j - \left[J^I J + \mu I\right]^{-1} J^I e \quad (9)$$

This algorithm is the fastest scheme for learning moderate-sized multilayer perceptron neural networks. There is an efficient application of the algorithm in MATLAB software; because the evaluation of the matrix equation in MATLAB is a built-in function therefore its attributes become even more pronounced.

4. MODEL OF SYNCHRONOUS MACHINE WITH MLP FFNN BASED PSS

The complete linearized model of synchronous generator with AVR and feedforward neural network based PSS is shown in figure 3 with their parameters. The input to the proposed power system stabilizer is speed/frequency and output is applied at the summing junction of the reference voltage [1, 6].

The methodology and results are discussed in detail to investigate the performance of a single machine infinite bus using MLP feedforward neural network PSS and comparing with conventional power system stabilizers.

A multilayer perceptron FFNN has been trained with the Levenberg-Marquardt back-propagation (BP) learning algorithm which is based on the supervised learning of artificial neural networks. The Levenberg-Marquardt BP is used because it is faster than the ordinary BP algorithm [7-8]. In this work, the network is trained to behave as a special type of a conventional controller. Inputs and target data for training of neural network are created from the input and the output of that controller in a closed loop fashion in conjunction with the plant.

Proposed MLP power system stabilizer is developed considering PID controller as input for the network during the training process. Neural network controller created in this way will have unique arrangement, which will remain constant once the training process is completed. The resulting controller includes more predictable characteristics which can be found in various types of self-adaptive control systems.

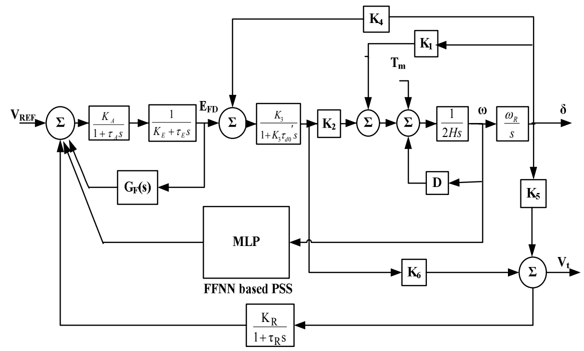

Figure 3: Linear model of synchronous machine with MLP FFNN based PSS

The selection of a suitable network structure is crucial for a particular application. A single hidden layer MLP network constitutes a universal approximation property. The network learns faster if hyperbolic tangent transfer function is used as the nonlinear activation function of hidden layer neurons. The number of hidden layer neurons is to be found by some trial and error procedure. Since the approach is based on the supervised learning of neural networks, hence the data for training (inputs and the target of the network) must be available. For this purpose, we recorded three inputs at the PID incoming signal and one output signal outgoing form PID. Figure 4 shows the MLP network for the model.

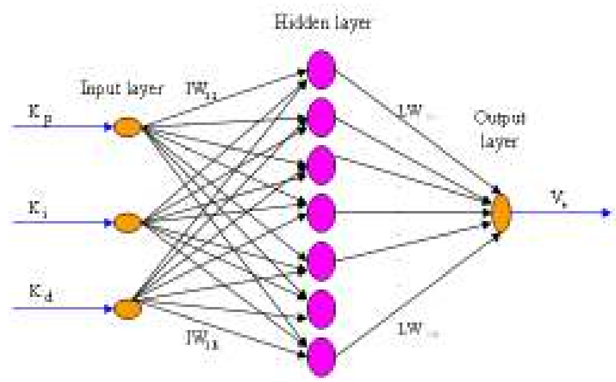

Figure 4: Multilayer perceptron network for PID power system stabilization

The three inputs of PID controller gain are applied as inputs to the input layer of the multilayer perceptron neural network. Terminal voltage and speed are the two required outputs of the proposed system.

A feedforward multilayer perceptron neural network has two layers. The first layer is a hidden layer which has weights coming from the input. It uses tangent sigmoid (tansig) transfer function. The second layer is the network output. The weights and biases are initialized and adapted with a specified learning scheme. The network is trained with specified hyperbolic tangent sigmoid transfer function. The performance of the network is measured according to the predetermined performance function. The learning parameters are as: Show = 5, i.e., after every 5th iteration the result is shown, Learning rate = 0.05, Epochs = 10000, it is the maximum number of iterations, Goal = 1e-6. For training of MLP network Levenberg-Marquardt BP supervised learning algorithm has been applied. This is the faster than the ordinary back-propagation algorithm.

5. SIMULATION RESULTS

5.1 At normal loading conditions

Transient responses of terminal voltages (V_t):
The transient responses of terminal voltages are shown below with normal loading conditions (P= 1.0 pu and Q= 0.62 pu). The simulation result of terminal voltage shows the transient responses with conventional and proposed PSS in figure 5. The settling and rise time characteristics show the improvement in transient responses with better applicability, suitability, simplicity, and efficiency of MLP-PSS over all other power system stabilizers.

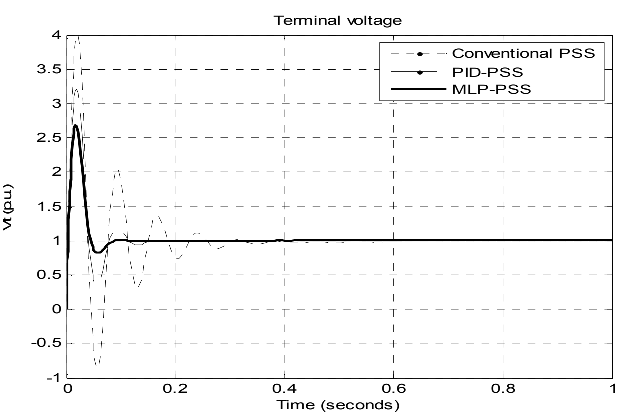

Figure 5: Combined responses of terminal voltage with conventional, PID and MLP-PSS

Dynamic performance of frequency deviation (Δω):
The performance of the proposed MLP power system stabilizer in case of dynamic response of speed/frequency deviation is investigated at loading conditions (P= 1.0 pu and Q= 0.62 pu) as shown in figure 6.

At normal loading conditions figure 6 shows the better settling and rise time characteristics of proposed PSS which improves dynamic responses with better performance in frequency deviation over all other conventional PSS.

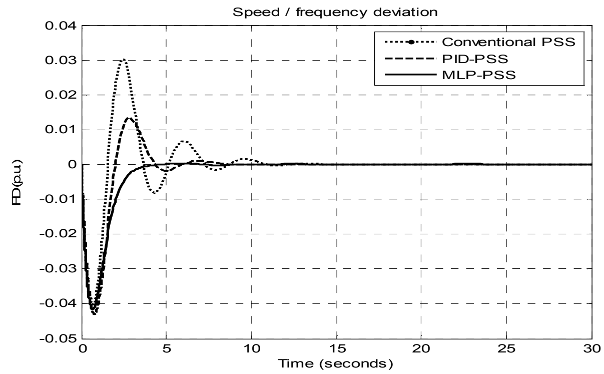

Figure 6: Combined response of frequency deviation with Conventional, PID and proposed MLP PSS

5.2 At 10% increase in loading conditions

Now the performance of the multilayer perceptron PSS is investigated by increasing a 10% load on the synchronous generator.

Transient responses of terminal voltages (V_t) at 10% increase

In figure 7, the terminal voltage response is investigated at 10% increase in step change after 0.4 seconds with conventional and proposed PSS.

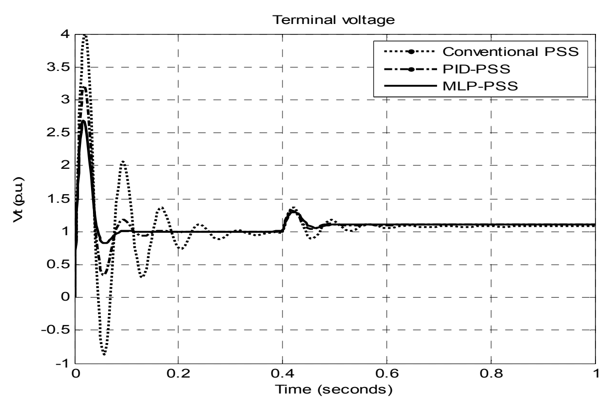

Figure 7: Combined response of terminal voltage with Conventional, PID and proposed MLP PSS at 10% change in load.

Dynamic performance of frequency deviation (Δω) at 10% increase:
Figure 8 shows that the dynamic responses of frequency deviations of all PSS at 10% increase in loading conditions after 0.4 seconds. Figure 7 and 8 compare the responses of a conventional and MLP PSS at 10% loading change and prove that the MLP is better for transient and dynamic responses.

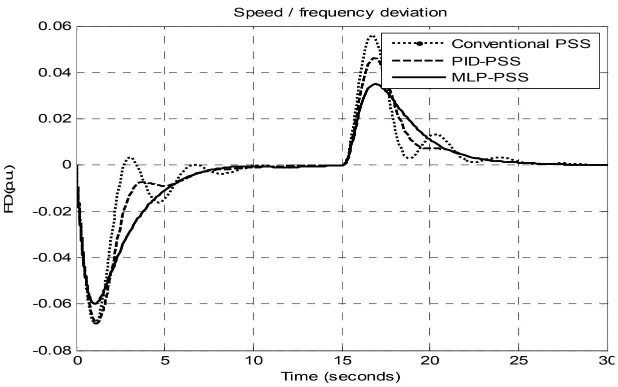

Figure 8: Combined responses of frequency deviation with Conventional, PID and MLP-PSS at 10% change in load.

6. CONCLUSIONS

In power system networks, low frequency oscillations have become a major concern for many years. In order to depress low frequency oscillation, the power system stabilizer parameters must be adjusted when there are changes in power network conditions.

This work proposes the suitable applicability of multi-layer perceptron feedforward neural network power system stabilizer as controller to tune the power system stabilizer parameters for achieving better enhancement in stability. MLPFFNN PSS is developed with the help of PID-PSS in parallel and compared the responses with the performances of transient and dynamic responses at normal and 10% changing in operation conditions. For training MLP neural network, real power and reactive power of synchronous machine are chosen as the input signals and the output are; the desired power network stabilizer parameters.

The simulation results with comparisons of rise time, settling time and overshoot indicate that the FFNN-PSS control system ensures improved performances in transient response of terminal voltages and dynamic stability in case of angular speed/frequency at normal as well as at changing operating conditions.

The particular conclusions concerned the MLP architectures:

- MLP networks architectures construct seven neurons in input (hidden) layer and its activation transfer function is hyperbolic tangent sigmoid. Only one neuron in output layer is created and its linear activation transfer function is ample for reasonable presentation.
- Popular back propagation with Levenberg-Marquardt algorithm is utilized for the upgrading in the training time.
- It is observed in this work, that a small number of hidden layer neurons are desirable for the development of MLP networks for the designing of power system stabilization system of electrical power system. .

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PERFORMANCE EVALUATION OF CONSTRUCTED WETLAND

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ABSTRACT

Constructed wetland is the biological wastewater treatment facility. These projects aim to treat wastewater and environmental sanitation problems through practical community based approaches. These problems confront the rapidly urbanizing cities in Asia. This is considered safe treatment and disposal method of wastewater. On the other hand conventional methods based on advanced technologies are simply not affordable or are complex to maintain in most medium and small sized towns. Constructed wetland is a complex assemblage of wastewater, substrate, and vegetation and an array of microorganisms. Vegetation has a vital role in the wetlands as it helps to serve in maintaining proper surfaces and a suitable environment for microbial growth of microorganisms and is a source of filtration. The collected samples indicate that physical, chemical and biological parameters are higher at the inlet as against NEQS. The same parameters show considerable reduction and acquire permissible levels at the outlet.

From experimental results it was derived that reduction rate of analyzed parameters such as COD, BOD, TDS, salinity, DO, TSS, nitrogen, phosphorous, Fecal coliform was effective. From the experimental work, it was found that this system is effective in reduction of pollutants from wastewater excluding dissolved oxygen. The overall removal efficiency remained up to 65%. This system reduced BOD, COD, and TDS, salinity, TSS, nitrogen, phosphorous, oil grease and fecal coliform by 94.4%, 89.5%, and 45.36%, 16.6%, 97.55%, 49.77%, 57.38%, 51.43% and 97.2% respectively. It was concluded that this treated wastewater through constructed wetlands could be used for the agriculture and aquaculture purpose.

Constructed wetlands are an effective option for on-site wastewater treatment when properly designed, installed, and maintained. Sub surface flow constructed wetlands are found to be a viable tertiary treatment alternative for municipal wastewater. These systems are potentially good, low-cost, appropriate technology treatment for domestic wastewater in rural areas where land is inexpensive.

Key words: ***Constructed wetland, substrate, permissible levels, NEQS***

1. INTRODUCTION

The chemistry of water is very interesting as it is the most abundant of all the compounds occurring in nature. It is essential to all forms of life. Apart from being essential to life, it plays a very important role in daily life. The human body is composed of 65 to 70 percent of water by weight and it is necessary to maintain most of our body functions. Water is important component of life. Earth is the only planet in the solar system to have abundant liquid water. In our homes water is used for drinking, cooking, washing and many other activities. In industry, it is used as a solvent, as a coolant and as an important chemical reagent. In agriculture, it is used for raising crops, which provide us with food and other necessities for our survival.

Grey water is that water which comes from kitchen, bathing, showers and laundry etc. Water coming from toilet is termed as black water. Many parts of the world are confronted with scarcity of water for both irrigation and human needs including Pakistan. Keeping in view the demand of water many countries have adopted to treat and recycle grey water for irrigation and other purposes. It is believed that about seventy to eighty percent water comes out from houses is grey water. Grey water treatment is simple as compared to the black water

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because black water treatment is complex and need advanced technology for treatment. Nitrogen content in black water is about ninety percent and it is very hard to extract nitrogen available in black water. Due to higher content of nitrogen makes it unfit for residential or commercial purpose (Elmitwalli and Otterpohl, 2007).

Municipal wastewater is a general term applied to liquid treated in a municipal treatment plant. Municipal wastes from towns frequently contain industrial effluents from dairies, laundries, bakeries, and factories, and those in large city may have wastes from major industries, such as chemical manufacturing, breweries, meat processing, metal processing, or paper mills. Human activity has affected the quantity and quality of water on earth. The future beneficial use of water will depend on our determination to employ new social, technical, economic, and political methods of dealing with water resources management. The reason these techniques are so necessary now is that we have reached a point in many areas where water demand exceeds the readily available supply. The opportunity of contributing to the prosperity of many millions of people by developing better management skills is an exciting challenge for those in water resources development (Cooper 1990).

Future challenges in technical aspects of water resources management are many. Our effects on fresh water over extraction and usage of freshwater resources are obvious almost all parts of the world. Fresh water over extraction is mainly for agriculture. The increasing demand of water for irrigation has significant impact on fresh water resources.

Constructed Wetland (CW) is a complex assemblage of wastewater, substrate, and vegetation and an array of microorganisms. Vegetation has a vital role in the wetlands as it helps to serve in maintaining proper surfaces and a suitable environment for microbial growth of microorganisms and is a source of filtration. Pollutants are removed within the constructed wetlands by different complex biological, chemical and physical processes.

The most commonly used hybrid system is a vertical flow (VF) followed by several stages of horizontal flow (HF) i.e. VF-HF constructed wetland which has been used for treatment of both sewage and industrial wastewaters. On the other hand, the use of a HF-VF system has been reported only for treatment of municipal sewage. Out of 60 surveyed hybrid systems, 38 have been designed to treat municipal sewage while 22 hybrid systems were designed to treat various industrial and agricultural wastewaters. The CWs with FWS units remove substantially more total nitrogen as compared to other types of hybrid constructed wetlands (Vymazal. J. 2013).

2. METHODS & MATERIALS

Constructed Wetland at village Majeed Keerio is designed, by keeping in view that the substrate of the Wetland can be rapidly filled up with debris, grit, and solids from raw wastewater, if these materials are not removed prior to the wetland through preliminary and primary treatment.

In CW at Majeed Keerio, filter beds are developed, which are actually known as a horizontal flow constructed wetlands (HFCW). These are shallow basins filled with filtering material such as rounded stone and bed is planted with different types of vegetation that has potential to survive in saturated conditions. Wastewater flows into the basin and also flows over the surface of substrate, the basin structure controls and is discharged out of the basin through a structure, which controls the depth of the wastewater in the wetland.

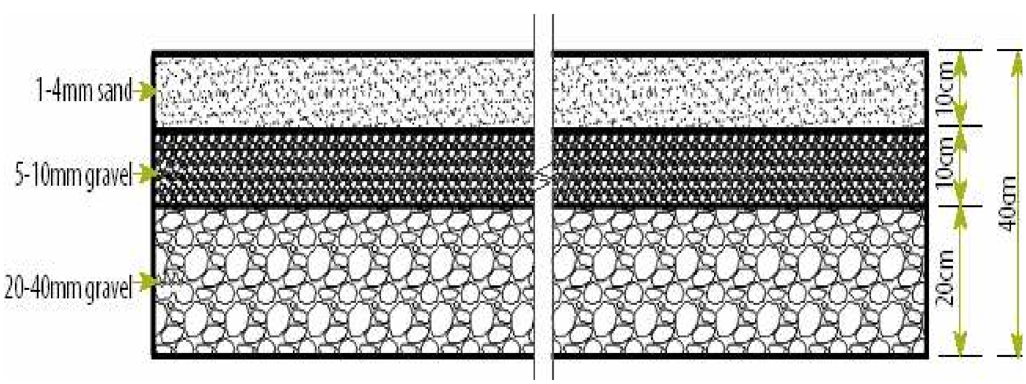

Figure 1: Sludge bed of CW Majeed Kerio.

Standard procedures and techniques used in civil engineering are applied for the basin construction of CW Majeed Keerio, which include earthwork in excavation, leveling and compaction. The importance of balancing the basin during construction cannot be under estimated. In order to protect the integrity of liner compaction of the sub grade is important during the construction of basin i.e. liner and gravel placement etc. These wetlands are graded level from side to side having a slope about 1% in the flow direction beams.

The geo membrane of 0.25mm is lined to prevent direct contact between the wastewater and groundwater. Preparation of sub grade under the liner is crucial for successful liner installation. The liner is covered with 3” RCC to cover the liner.

The cross sectional view of the constructed wetland at Majeed Kerio is shown in Fig.1. Whereas the water flow arrangements of CW at Majeed Kerio is shown in Fig. 2.

Figure 2: Water flow arrangements of CW Majeed Keerio

3. OBJECTIVES OF RESEARCH

The main objectives of this research work are as under:

1. To analyze the treatment efficiency of constructed wetland.
2. To measure the Quantity & Quality of wastewater.
3. To check the results incompliance with NEQS Pakistan.

4. QUANTITATIVE ANALYSIS

Quantification of wastewater entering in constructed wetland and discharging from it after treatment was performed. The rate of flow at inlet and outlet was measured in gallons per day at the time of collection of samples for laboratory analysis. The details of flow at inlet and outlet are shown in table 1.

Table 1: Flow of water at inlet, and outlet during sample collection

S. No	Date	Inlet (Gallons/Day)	Outlet (Gallons/Day)
1	01-01-2012	75300	74100
2	15-01-2012	74600	70200
3	29-01-2012	74950	70050
4	12-02-2012	72100	70600
5	27-02-2012	63900	60900
6	12-03-2012	56500	54030
7	26-03-2012	71000	68200

5. QUALITY ANALYSIS

Quality analysis of samples focused on following para-meters in order to compare concentration in accord-ance to permissible level in the National Environmental Quality Standards (NEQS).

a) Biochemical Oxygen Demand (BOD)

According to the National Environmental Quality Standards provided for industrial and domestic effluents biochemical oxygen demand limit is set 150mg/l. The analyzed values of biochemical oxygen demand at inlet and outlet samples of constructed wetland are presented in Fig 3.

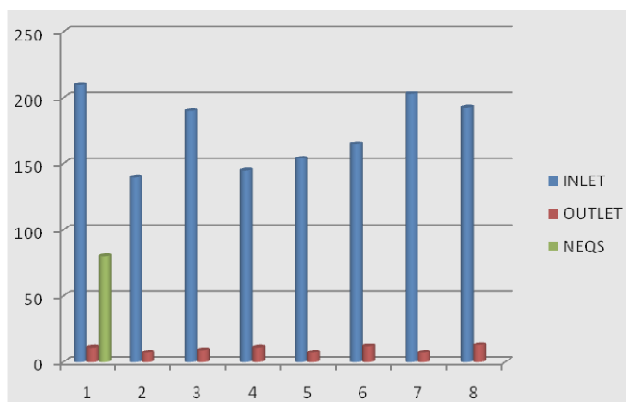

Figure 3: Graphical presentation of BOD values of CW Majeed Keerio

The obtained data shows that all values were in range of NEQS Pakistan after treatment through constructed wetland. An average value at inlet point was 104.75mg/l and at outlet it was recorded 9.625mg/l. The highest value at the inlet was recorded 125mg/l and the highest value at outlet was recorded 13mg/l respectively. The results of all samples indicate that BOD values were within NEQS limit but untreated wastewater cannot be used for irrigation purpose having high BOD level, for irrigation purpose grey water must be treated. After treatment through constructed wetland water can be reused for vegetation and irrigation purpose without causing any health hazard.

b) Chemical Oxygen Demand (COD)

According to the National Environmental Quality Standards provided for industrial and domestic effluents into sea Chemical Oxygen Demand (COD) limit is set 180mg/l. The analyzed values of chemical oxygen demand at inlet and outlet samples at constructed wetland are presented in Fig. 4. The obtained data shows that all values were in range of NEQS Pakistan after treatment through constructed wetland. An average value at inlet point was observed 782mg/l and at outlet it was recorded 110mg/l. The highest value at the inlet was recorded 910mg/l and the highest value at outlet was recorded 146mg/l respectively. COD values of constructed wetland treatment plant of Majeed Keerio before the treatment was not within the permissible limit while after the treatment of wastewater it was within the NEQS limits. Wastewater that contains high level of chemical oxygen demand poses great threat to aquatic life and is the major cause of water quality degradation.

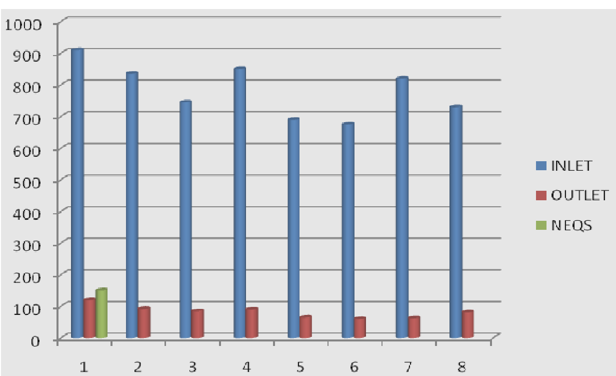

Figure 4 Graphical presentations of COD values of CW Majeed Keerio

c) Total Suspended Solids (TSS)

According to the National Environmental Quality Standards provided for industrial and domestic effluents total suspended solids limit is 200mg/l. The obtained data shows that all values were in range of NEQS Pakistan after treatment through constructed wetland. An average value at inlet point was observed 507.62mg/l and at outlet it was recorded 12.88mg/l. The highest value at the inlet was recorded 690mg/l and the highest value at outlet was recorded 35mg/l respectively. The graphical presentation of total suspended solids is given in fig. 5. The results indicate that the quantity of total suspended solids is not at higher side. It also indicates that the suspended solids are settled in sedimentation pond.

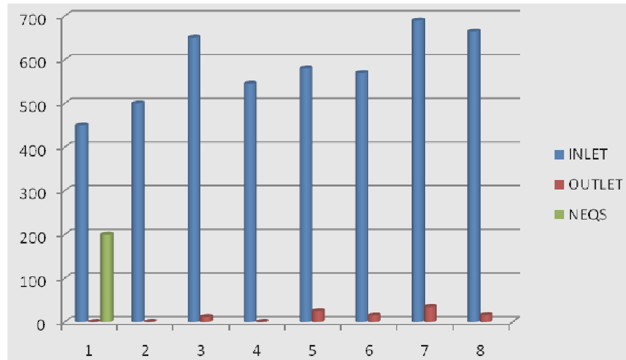

Figure 5 Graphical presentations of TSS values of CW Majeed Keerio

d) Total Dissolved Solids (TDS)

According to the National Environmental Quality Standards provided for industrial and domestic effluents total dissolved solids limit is set 3500mg/l. The analyzed values of total dissolved solids at inlet and outlet points provided for collection of samples at constructed wetland are presented in Fig.6.

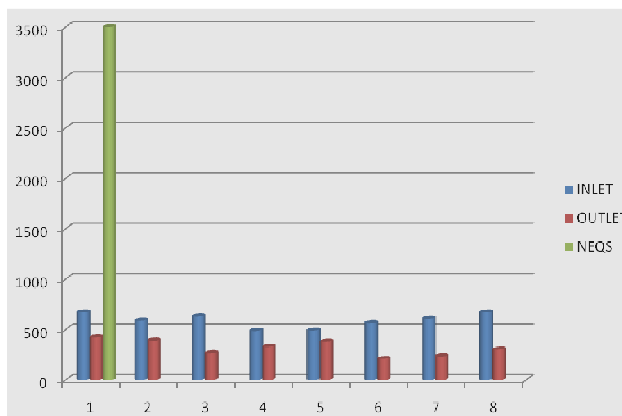

Figure 6 Graphical presentations of TDS values of CW Majeed Keerio

The obtained data shows that all values were in range of NEQS Pakistan before and after treatment through constructed wetland. An average value at inlet point was observed 589.25mg/l and at outlet it was recorded 286.62mg/l. The highest value at the inlet was recorded 670mg/l and the highest value at outlet was recorded 421mg/l respectively. The results indicate that TDS values were found incompliance to NEQS limit of

3500mg/l for all samples. As water is a universal solvent, it dissolves a wide range of substances such as calcium, magnesium, carbonate, chlorides and many other substances. Fresh water, brackish water and seawater differ primarily in their level of total dissolved solids.

e) OIL AND GREASE CONTENT

The average values of oil and grease samples collected at inlet and outlet were recorded 17.25mg/l and 8.12mg/l respectively. Permissible limit for oil and grease concentration as per NEQS for domestic and industrial effluent is 10.0mg/l. The graphical presentation of values is shown in figure 7. Improper disposal of effluent containing high levels of oil and grease can result in high biological oxygen demand (BOD) and high chemical oxygen demand (COD) levels, increased operating costs, and clogging of collection systems.

After performing analysis of oil and grease tests it was deduced that the highest value at the inlet was recorded 17.25mg/l and the highest value at outlet was recorded 8.12mg/l respectively. The results indicate that oil and grease values come under NEQS limit after treatment through constructed wetland. It shows that oil and grease was within permissible limit after treatment.

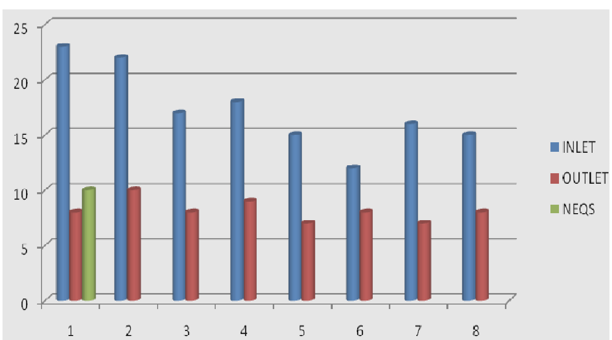

Figure 7 Graphical presentations of oil & grease values of CW Majeed keerio

6. CONCLUSION

From experimental results it was deduced that reduction rate of parameters BOD, COD, TSS, TDS and oil & grease is effective. From experimental work, it was found that this system is effective in reduction of pollutants from wastewater excluding dissolved oxygen. The overall removal efficiency remained up to 65%. This system reduced BOD, COD, TSS, TDS and oil grease by 94.4%, 89.5%, 97.55%, 45.36%, and 51.43% respectively. It is concluded that this treated wastewater through constructed wetlands could be used for the agriculture and aquaculture purpose. From experimental study, it was found that dissolved oxygen of wastewater was increased due to treatment of municipal wastewater through constructed wastewater.

7. ACKNOWLEDGEMENT

The authors highly acknowledge the cooperation extended by World Wide Fund (WWF), the energy and environment engineering department, QUEST, Nawabshah and local government authorities.

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UNIPRIMITIVE GROUPS OF DEGREE $\frac{1}{2}n(n-1)$

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ABSTRACT

The goal of this paper is to study the order and sub-groups of a uniprimitive groups of degree $\frac{1}{2}n(n-1)$, where n is an integer and greater than 4 $(n \in Z > 4)$, where the sub-degrees, sub-orbit lengths of these groups are also investigated in this work. Along with carrying the survey on the area of the groups and their properties it is also pointed out that the particular generalizations will be useful for the further investigations and interpretation of uniprimitive groups. In this paper we prove the result which is based on the properties of uniprimitive groups.

Keywords: ***Symmetric Group, uniprimitive, primitive, sub-degrees, sub-orbits lengths, and permutation.***

INTRODUCTION

The study of primitive group having small degree has a wide and well known past. This short introduction is based on the historical background and some important developments on primitive groups by some of the authors are given in this presentation. The study of permutation groups of degree less than 1000 has been discussed in [5]. Later on the research on the Primitive Permutation Groups of Degree Less Than 4096 was explored and compared with past studies by Hanna J. Coutts et al [3]. P. J. Cameron [9] has given the idea of Finite Permutation groups and Finite Simple groups in wide aspect.

The study of permutation group is essential for exploring advanced study on uniprimitive groups. Before we present our results (axioms, theorems) on uniprimitive groups, it is necessary to know about few famous related necessary results on Permutation groups.

Definition: A subgroup of the symmetric group G on a set S is called a permutation group or group of permutations.

Definition: For any non-empty set G, the set of all even permutations of G_n is a subgroup of G_n, hence the set of all even permutations of G_n is called the irregular group on n elements, and will be denoted by G_n.

We refer the reader for the overview of uniprimitive groups of degree 120 to [6] where such types of properties for these groups are investigated. Our goal is to generalize these results to the uniprimitive groups of degree $\frac{1}{2}n(n-1)$. For basic definitions, notations and preliminary results in permutation groups, we refer the reader to H. Wielandt [4] and for the representation theory and group characters the reader is referred to M. Burrow [8]. We propose the following main result:

THEOREM:

The symmetric group S_n is uniprimitive of degree $\frac{1}{2}n(n-1)$ acting on unordered sets, where $S_n + 1$ is not square. The sub-degrees are $1,\ (n-1),\ \frac{1}{2}n(n-3)$ and sub-orbit lengths are

$$1,\ 2(n-2),\ \frac{1}{2}(n-2)(n-3).$$

PROOF:

Consider $G = S_n$ acting naturally on $\Phi = \{1, 2, 3, \cdots, n\}$, then Facts on $\Omega = \{A \subseteq \Phi |^{*} |A| = 2\}$, the set of $\left|\begin{matrix} n \\ 2 \end{matrix}\right. = \frac{1}{2}n(n-1)$ unordered sets i.e.

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$\Omega = \{1, 2\}, \{1, 3\}, \cdots, \{1, n\}, \{2, 3\}, \{2, 4\}, \cdots,$
$\{2, n\}, \cdots, \cdots, \{n-1, n\}$

G is transitive but not doubly transitive on Ω, because there is no element in G, this takes $\{1, 2\}$ to $\{1, 2\}$ and $\{1, 3\}$ to $\{4\ 5\}$. We find orbits of $G\ \{1, 2\}$, i.e. sub-orbits of G on Ω. Let $g \in G$, then $g \in G_{\{1, 2\}}$, iff $\{1,2\} \hat{g} = \{1,2\}$, equivalently g either fixes or transpose 1 and 2, and may induce any permutation on $\{3, 4, \cdots, n\}$.

Hence,

$\{1, 3\}, \{1, 2\} = \{1, 3\}, \{1, 4\}, \cdots,$
$\{1, n\}, \{2, 3\}, \{2, 4\}, \cdots, \{2, n\}$

this is the set of all unordered sets containing exactly one of 1 and 2. $\{3, 4\} G_{\{1, 2\}} = \begin{Bmatrix} \{3, 4\}, \{3, 5\}, \cdots, \{3, n\}, \{4, 5\}, \\ \{4, 6\}, \cdots, \{4, n\}, \cdots, \{n-1, n\} \end{Bmatrix}$

Hence, the orbits of $G_{\{1, 2\}}$ or sub-orbit of G have lengths $1,\ 2(n-2),\ \frac{1}{2}(n-2)(n-3)$. Now we prove that G is primitive. If G is not primitive (imprimitive), then G has a block of non-primitives ψ. The length of ψ divides $|\Omega| = \frac{1}{2}n(n-1)$ and is a union of some orbits of $G_{\{1, 2\}}$, not true orbits of $G_{\{1, 2\}}$ which have the length $1,\ 2(n-2),\ \frac{1}{2}(n-2), \frac{1}{2}(n-2)(n-3)$. Therefore G is primitive and hence unimprimitive.

Again we find the degrees of irreducible characters G, i.e. sub-degrees of G.

Let $\{^f\alpha\}, \Delta(\alpha), \Gamma(\alpha)$, be sub-orbits of G with lengths $1,\ 2(n-2),\ \frac{1}{2}(n-2)(n-3)$ respectively $(\alpha \in \Omega)$. Then we recall the following result from the lemma 2 of Higman [4],

$$|\Delta(\alpha)\,\eta(\beta)| = \begin{cases} \lambda & for \quad \beta \in \Delta(\alpha) \\ \mu & for \quad \beta \in \Gamma(\alpha) \end{cases}$$

By lemma 5 of D. G. Higman [2],

$$\mu\ell = k(k-\lambda-1)$$

putting $k = |\Delta(\alpha)| = 2(n-2)$ and

$$\ell = |\Gamma(\alpha)| = \frac{1}{2}(n-2)(n-3)$$

then we get

$$\frac{1}{2}(n-2)(n-3)\mu = 2\,(n-2)\{2\,(n-2) - \lambda - 1\}$$
$$\Rightarrow (n-3)\,\mu + 4\lambda = 4(2n-5)$$

The possible solutions are

Case(i):

$\mu = 4, \quad \lambda = n-2$,

Now $|G|$ is even because $|\Omega| = 120$ divided $|G|$.

Hence by II lemma 7 of [2],

$d = (\lambda-\mu)^2 + 4\,(k-\mu)$ is perfect square.

Case(ii)

if $\mu = 8, \lambda = 1$, and $k = 2(n-2)$ then by simplification , we get

$$d = 49 + 8n - 48$$
$$\Rightarrow d = 8n + 1$$

Therefore d is not perfect square.

Therefore, the selections $\mu = 8,\ \lambda = 1$, and $k = 2(n-2)$, is not possible.

Case (iii)

Now If we take $\mu = 4, \quad \lambda = n-2$ and $k = 2(n-2)$,

Then

$$d = (n-6)^2 + 4(2n-8)$$
$$= (n-1)^2$$

Therefore d is perfect squared.

By (2, p. 150)

$$f_2, f_3 = \frac{2k + (\lambda - \mu)(k+\ell) \mp \sqrt{d\,(k+\ell)}}{\mp\sqrt{d}}$$

Putting the values of $d, k, \ell, \lambda, \mu,$ then we get

$$f_2 = (n-1) \text{ and } f_3 = \frac{1}{2}n(n-3)$$

Hence proof the statement of theorem.

CONCLUSION:

Study of uniprimitive groups is given in this paper where we have generalized the degree of uniprimitive groups from 120 to $\frac{1}{2}n(n-1)$, with $n \in Z > 4$, moreover we have investigated the sub-degrees, sub-orbit lengths of the groups discussed in this paper. The results and the possible case study of the problem is given in the main theorem.

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VARIABLE REFERENCE FREQUENCY TRACKING OF SECOND ORDER VOLTAGE SWITCHED CP-PLL

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ABSTRACT

The charge-pump phase locked loop (CP-PLL) is widely utilized integrated circuit for different applications in communication for frequency generations and tracking. The linear models are not applicable to explore the system dynamics when a variable reference frequency is applied to the system, because of their limited validity in the locked state (i.e. for small phase variations). However the discrete-time non-linear models are advantageous over linear model in characterizing the model behavior when the CP-PLL is initially acquiring the lock on to phase of the reference signal. In this paper, the non-constant reference frequency is applied to both voltage and current switched CP-PLL systems using the event driven technique. The weakly damped dynamics of the voltage switched system limits its performance while tracking the ramping reference frequency due to its varying pumping current characteristics.

Keywords: ***Phase-locked loop, Phase and frequency detector, voltage switched charge-pump. Event driven model, ramping frequency.***

1. INTRODUCTION

The charge-pump phase locked Loop (CP-PLL) is the main subsystem utilized in various applications in wireless communications to industrial electronics (Gardner, 1980; Best, 1984; Margaris, et al, 1985; Ehsan, et al 2012; Weigand, et al, 2011, Brain, et al 1996). The CP-PLL is basically a negative feedback system used to synchronize two signal sources in frequency and phase. The phase detecting unit compares two incoming signal at it inputs (one coming from the reference and other is feedback signal) and detects the phase misalignment in the digital form. The charge-pump (CP) circuit translates the logical outputs of phase detector, encode the phase error signal into a corresponding current or voltage output. Then it is applied to the loop filter (LF) to remove the high order frequency contained in detector signal $\upsilon_{\mathrm{d}}(t)$, and produces a quasi-dc signal which tunes the frequency of the voltage controlled oscillator (VCO).

The CP-PLL has major role in frequency synthesis, a feedback divider depending on the requirement of system (integer or fractional) is implemented in the feedback loop, divides the loop in high and low frequency parts. The current switched charge-pump (CSCP) produces ideally a balanced pump current $i_{\mathrm{P}}(t)$ while speeding up and slowing down the loop dynamics. Many comer-cially CP-PLL ICs (like 4046) incorporate a voltage switched charge pump (VSCP), since the design of such circuit is simple. However including a VSCP enhance the complexity in the dynamical behavior due to the variation

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in the pump current (Gardner, 1980; Best, 1984; Margaris, et al, 1985; Ehsan, et al 2012). To study these effect while non-linear acquisition and locking regions, it requires a systematic approach. Mixed-mode nature of the CP-PLL cannot be explored using any general theory (Christian, et al, 1999 ; Brain, et al 1996).

To characterize the system level behavior different modeling approaches of the CP-PLL exist, e.g. linear s-domain and z-domain models, and discrete time non-linear models (Ehsan, et al 2012 ; Wiegand, et al 2011; Christian, et al, 1997 ; Christian, et al, 1999 ; Paemal, 1994). Linear models are limited to the locked state of the CP-PLL however discrete-time non-linear event driven models are more powerful for the institutive designs, characterization and analysis. In this paper, the second order voltage switched CP-PLL is subjected to the variable reference frequency and it tracking behavior is compared to current switched CP-PLL.

Section II focus on the architecture of CP-PLL system. Event driven modeling in described in the section III. Numerical method is given in section IV. Section V discuss the reference ramping and the simulation result for both architectures of the PLL. Section V summerises the conclusions.

II. ARCHITECTURE

The system level components arranged in the loop are representing the basic architecture of the CP-PLL as shown in Fig.1.

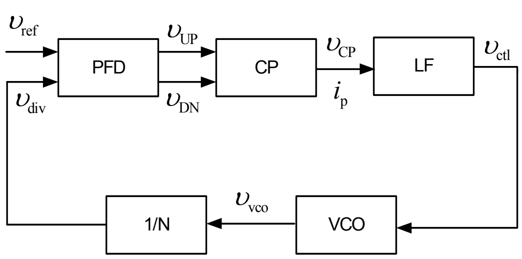

Figure.1: Basic architecture of the CP-PLL.

Phase and Frequency Detector (PFD): The PFD is a digital phase detector which compares the two incoming signals and generates a digital output to command the charge-pump circuit (Best, 1984; Paemal, 1994, Brain, et al, 1996).

Charge-Pump (CP): The CP circuit is controlled by the edge sensitive phase detector circuit and it translates the phase error signal of the PFD into an appropriate analog signal. The charge pumped or removed is proportional the pulse width of the phase error (Gardner, 1980; Best, 1984; Margaris, et al, 1985; Ehsan, et al 2012; Christian, et al, 1997; Christian, et al, 1999). The voltage switched charge-pump (VSCP) provides supply voltage to the loop filter, which results in non-constant pump current for three states of the PFD. The VSCP is easier to design than a constant current charge-pump (Best, 1984, Margaris, et al, 1985). However it adds a non-linear characteristic in the pumped current to and from the loop filter (Best, 1984; Margaris, et al, 1985, Ehsan, et al, 2012).

Loop Filter (LF): The LF integrates the pump current to set an average frequency. It is used to smooth the detected signal and suppresses the higher order harmonics in the CP-PFD output signal and passes the low order harmonics only (Gardner, 1980; Best, 1984; Margaris, et al, 1985; Ehsan, et al 2012; Christian, et al, 1997;). The linear, time-invariant differential equation of the lead-lag loop filter is represented as

$$\sum \mathrm{LF}: \begin{cases} \dot{x}(t) = \mathrm{A}\, x(t) + \mathrm{B}\, \upsilon_{\mathrm{d}}(t) \\ \upsilon_{\mathrm{ctl}}(t) = \mathrm{C}^T x(t) + \mathrm{D}\, \upsilon_{\mathrm{d}}(t) \end{cases} \tag{1}$$

Voltage Controlled Oscillator (VCO): The VCO is the heart of PLL systems that outputs an oscillating signal with a frequency proportional to the quasi-dc voltage $\upsilon_{\mathrm{ctl}}(t)$ applied to its control node ((Christian, et al, 1997; Paemal, 1994). VCO tuning characteristics are usually represented in a nonlinear curve. However when PLL is locked, $\upsilon_{\mathrm{ctl}}(t)$ varies around a small region and the VCO frequency is represented as

$$\omega_{\mathrm{vco}}\left(\upsilon_{\mathrm{ctl}}(t)\right) = K_{\mathrm{v},\omega}\upsilon_{\mathrm{ctl}}(t) + \omega_{\mathrm{v}\phi} \tag{2}$$

ω_{vco} is angular frequency of the VCO.

$K_{\mathrm{v},\omega}$ is the gain (in rad/sec/V).

$\omega_{\mathrm{v}\varphi}$ is the free running angular frequency.

1/N: The frequency divider is implemented in the feedback loop (Fig.1) in order to perform frequency synthesis function (Christian, et al, 1997; Paemal 1994, Brain, et al 1996). Depending on the requirement the divider can be integer or fractional. Following frequency is generated from the VCO in when the PLL is in the steady state:

$$f_{\mathrm{ref}} = \frac{f_{\mathrm{vco}}}{N} \Rightarrow f_{\mathrm{vco}} = N \bullet f_{\mathrm{ref}} \tag{3}$$

III. Event Driven Modeling

The Event Driven technique is based on calculating the commutation instant of two incoming signal. The time point at which effective edge of the signal triggers the PFD is taken into account (see Fig.2). Depending on the calculated time instant phase of the reference and feedback signal is calculated (Ehsan, et al, 2012; Christian, et al, 1997; Christian, et al, 1999). For that, the

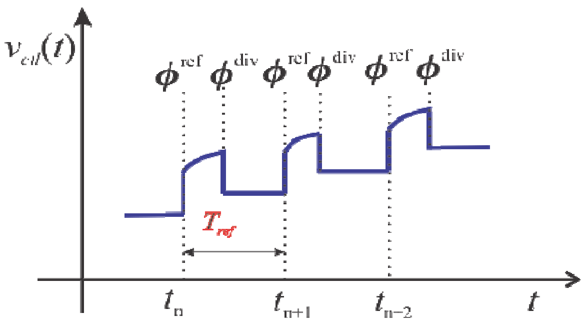

Figure 2: Event-Driven Technique.

non-linear discrete-time event driven phase equations

$$\phi^{ref}(t_{n+1}) = \phi^{ref}(t_n) + \int_{t_n}^{t_{n+1}^{ref}} \omega_{ref}(t')dt' \quad (4)$$

$$\phi^{div} = \phi^{div}(t_n) + \int_{t_n}^{t_{n+1}^{div}} \omega_{div} \upsilon_{ctl}(t')dt' \quad (5)$$

of respectively the reference and the divider signals have to be solved:

t_{n+1}^{ref} is the solution of $\varphi_{ref}(t_{n+1}^{ref}) = 2\pi$ (6.a)

t_{n+1}^{div} is the solution of $\varphi_{div}(t_{n+1}^{div}) = 2\pi$ (6.b)

- t_{n+1}^{ref} is the falling edge of the reference signal.
- t_{n+1}^{div} is the falling edge of the divider signal.

The effective falling edge is the one first occurring at:

$$t_{n+1} = \min(t_{n+1}^{div}, t_{n+1}^{ref}) \quad (7)$$

Assuming a constant or a non-constant (i.e. ramp) reference signal (see in Fig.3), (5.a) leads to a simple analytical solution for t_{n+1}^{ref}.

However the divider phase equation (5.b) for the voltage switched CP-PLL (VSCP-PLL) is a transcendental expression and t_{n+1}^{div} has to be calculated using numerical method.

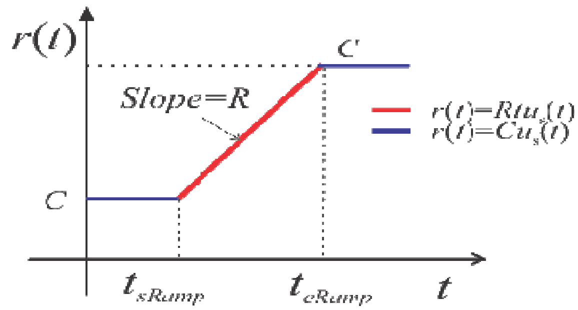

Figure 3: Representing the step $r(t) = Cu_s(t)$ and ramp $r(t) = Rtu_s(t)$ function.

IV. Numerical Solving: Secant Method

The secant method is an iterative root finding numerical method. It requires one function evaluation (e.g. Newton-Raphson method requires two functions) so that if the algorithm converges than it is even fast than other methods.

$$t_1 = t_2 - \frac{\phi^{div}(t_2)(t_2 - t_0)}{\phi^{div}(t_2) - \phi^{div}(t_0)} \quad (8)$$

To determine the solution $t_1 = t_{n+1}^{div}$ the algorithm converges to the condition $\varphi^{div}\left(t_{n+1}^{div}\right) \equiv 2\pi$.

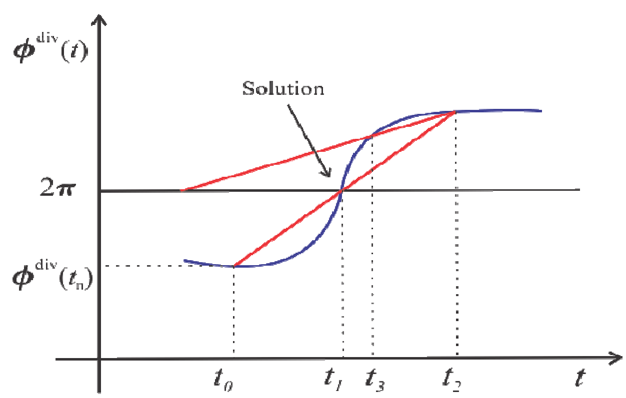

Figure 4: Determination of falling event from divider $t_n = t_{n+1}^{div}$ using the secant method (this is a simple example of the convergence).

V. Variable Reference Frequency Applied to the Second Order VSCP-PLL

Due the versatility of the CP-PLL, it can be applied to track the reference ramp generator (Mush, T, 1998, Christian, H, 1997). The event driven technique is the most powerful tool to study the dynamic behavior and it allows applying a ramp input frequency to test the tracking ability of the VSCP-PLL (Ehsan et al, 2012, Christian, H, 1999). The input frequency step for the linearly varying ramp must be within lock range of PLL to track it (Best, 1984). Equation (9) represents the inequality that must be satisfied for the slope (β) of the reference frequency ramp to be tracked by the oscillator (Gardner, F, M 1979). This inequality belongs to the constant current system (i.e. current switched CP-PLL). Nevertheless, it is also valid for second order VSCP-PLL using an equivalent model of the CSCP-PLL.

$$\left|\varphi_{\text{err}}^{\text{static}}\right| \leq 2\pi \Leftrightarrow \beta \leq \frac{K_{\text{v},\omega} I_{\text{p}}}{N C_1} \tag{9}$$

Since the VSCP produces non-constant pump current $i_{\text{p}}(t)$ as a function of electrical load of LF, which limit-- - --the ability of the system when tracking the ramp function of the frequency.

$$i_{\text{p}}(t) = \frac{V_{\text{CP}} - \upsilon_{\text{C1}}(t)}{R_0 + R_1} \tag{10}$$

As soon as the capacitor voltage $\upsilon_{C1}(t)$ approaches V_{CP} , the pump current reaches its minimum.

a. SIMULATION RESULT

The event driven model of the second order CP-PLL is subjected to a reference generator ramp. Here both systems (CSCP-PLL & VSCP-PLL) are considered as shown in Fig. 5. The Fig. 5 is divided in differemt zones A...G.

In zone-A, both systems are showing an erratic behavior before locking to the target frequency (1MHz). Both models are locked and settled in the zone-B. The ramping frequency (1MHz to 3Mhz) is applied in zone-C, the positive frequency ramp starts at 200µs and ends at 433µs and reaches a target frequency of 3MHz. The phase error $\phi_{\text{err}}(t)$ of the VSCP-PLL is not converging to a constant value (unlike CSCP-PLL, which is converging to a constant value) but it is increasing during the ramp tracking period. This is the consequence of week pump current (10). Settling behavior of both systems can be seen in the zone-D, which describes the equivalent behavior of both systems. In the zone-E, it is obvious that, CSCP-PLL is tracking a bit longer ramp inclination of reference frequency with a negative slope, but the VSCP-PLL is *pulled-out* of the lock (circled area in the phase transient) in zone-F, however CSCP-PLL is efficiently tracking in this region. In the zone-G, after unlocking, once again the VSCP-PLL acquires the lock and it is settled. The voltage switched system exhibit the lack of ability in tracking a ramp, whereas similar ramp is completely followed by the CSCP-PLL, on the other hand, CSCP-PLL continues tracking without losing the lock. The phase-plane of the both systems is shown in Fig. 6, which shows that after an erratic region the system is converged to a target frequency, the system settles three times in the steady state.

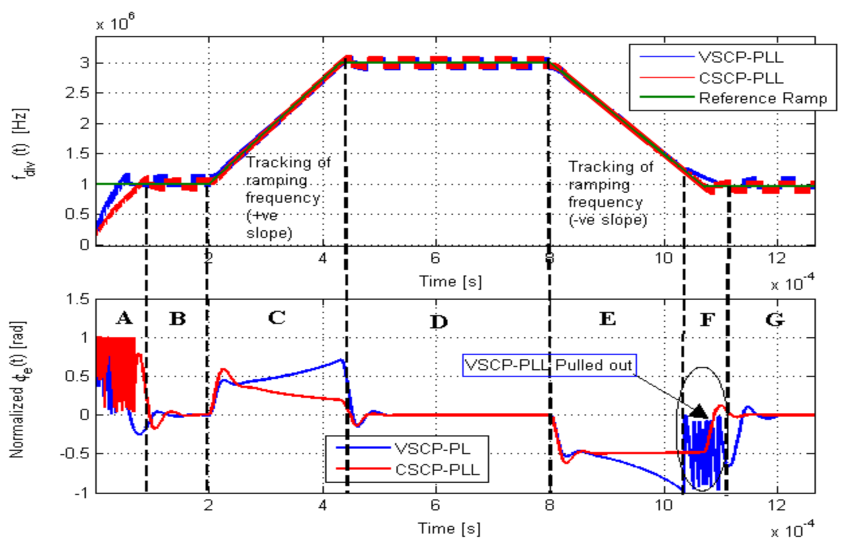

Figure 5: The phase error response of the both CSCP-PLL and VSCP-PLL to two successive reference frequency-ramps.

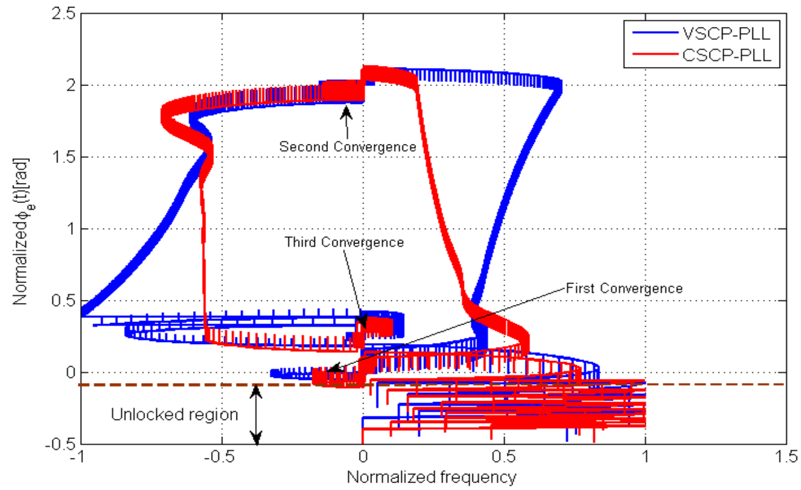

Figure 6: The phase-plane of both CSCP-PLL and VSCP-PLL when tracking two successive reference frequency-ramps.

VI. CONCLUSION

The event driven model of the voltage switched CP-PLL was subjected to the variable reference frequency. It shows that week dynamics due the non-constant pump current influences the dynamical behavior of the second order VSCP-PLL. This peculiarity limits its performance in tracking a ramping reference frequency. On other hand the CSCP-PLL has strong dynamics due to its ideally constant pump currents and it can track a variable frequency within the inequality condition described. The designer must be careful to pump current conditions to meet a desired accuracy for frequency tracking applications.

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