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SPREADSHEET MODELING OF THERMAL INSULATION IN DEEP WATER FLOW LINES

Strictly as per the compliance and regulations of:

Spreadsheet Modeling of Thermal Insulation in Deep Water Flow Lines

D.P.S Abam[1], V. Adukwu[2]

Abstract-A model has been proposed to calculate the optimal thermal insulation layer thickness of flow lines in deep water. The developed model is used in excel spreadsheet to simplify the procedures necessary for the calculations. The hydrate and wax formation temperatures is first known and critical radius of insulation is calculated to obtained the required thickness of insulation in order to mitigate cool down of the fluid. The study presents three analytical heat transfer solutions of deepwater flow lines for the determination of an appropriate insulation layer thickness. The model has been used to determine the optimal insulation thickness for a deep water flow line using three different insulation materials; Polyethylene, Polypropylene and Polyurethane.

I. Introduction

Heat transfer across the insulation of flow lines presents a unique problem affecting flow efficiency. Although sophisticated computer packages are available for predicting fluid temperature, their accuracies suffer from numeric treatments because long pipe segments have to be used to save computing time. This is especially true for transient fluid flow analysis in which a very large number of numerical iterations are performed.

The thermal performance of subsea production system is controlled by the hydraulic behavior of fluid in the flow line; conversely, it also impacts the hydraulic design indirectly through the influence of temperature on fluid properties such as gas-oil ratio (GOR), density, and viscosity. Thermal design, which predicts the temperature profile along the flow line, is one of the most important parts in the flow line design; and this information is required for pipeline analyses including expansion analysis, upheaval or lateral buckling, corrosion protection, hydrate prediction and wax deposition analysis. In most cases, the solids managements (hydrate, wax, asphaltenes, and scales) determine the requirements of hydraulic and thermal designs. In order to maintain a minimum temperature of fluid to prevent hydrate and wax deposition in the flow line, insulation layers may be added to the flow line.

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Thermal design includes both steady state and transient heat transfer analyses. In steady state operation, the production fluid temperature decreases as it flows along the flow line due to the heat transfer through pipe wall to the surrounding environment. The temperature profile in the whole pipeline system should be higher than the requirements for prevention of hydrate and wax formation during normal operation and is determined from steady-state flow and heat transfer calculations. If the steady flow conditions are interrupted due to a shut-in or restarted again during operation, the transient heat transfer analysis for the system is required to make sure the temperature of fluid is out of the solid formation range within the required time. It is necessary to consider both steady state and transient analyses in order to ensure that the performance of the insulation coatings will be adequate in all operational scenarios.

The most severe operational hazards of offshore pipelines are the risks associated with the transportation of multiphase fluids (Boyun and others, 2005). When water, oil and gas are flowing simultaneously inside the pipeline, there are quite a few potential problems that can occur: water and hydrocarbon fluids can form hydrate and block the pipeline; wax and asphaltene can deposit on the wall and may eventually block the pipeline; with high enough water cut, corrosion may occur; with pressure and temperature changes along the pipeline and/or with incompatible water mixing, scales may form and deposit inside the pipeline and restrict the flow; and severe slugging may form inside the pipeline and cause operational problems to downstream processing facilities. The challenge that engineers will face is, thus, how to design the pipeline and subsea system to assure that multiphase fluids will be safely and economically transported from the bottom of the wells all the way to the downstream processing plant. The practice of identifying, quantifying, and mitigating of all the flow risks associated with offshore pipelines and subsea systems is called flow assurance.

Flow assurance is critical for deepwater pipeline and system operations. In deepwater, the seawater temperature is usually much colder than the surface air temperature. When pipeline is submersed in the deep water, if there is no thermal insulation layer surrounding the pipe wall, the fluid heat can be quickly lost to the water. This is especially true if the water current around the pipeline is strong. With an un-insulated pipeline, the heat transfer coefficient at the outer pipe wall can be significant due to the forced convection by the seawater movement (Yong and Qiang, 2005). If the fluid temperature inside the pipeline becomes too low due to the heat loss, water and hydrocarbon (oil and gas) may form hydrate and block the flow. Furthermore, if the fluid temperature is low enough, wax may start to precipitate and deposit on the pipe wall. Thus, effective preservation of fluid heat is one of the most important design parameters for offshore pipeline.

In deep water, the pipeline is normally followed by a production riser which goes from the sea bottom to the surface processing facilities (topsides). The deeper the water is, the longer the production riser is. With a long riser, the pipeline operating pressure will be higher due to the hydrostatic head in the riser. For the same fluid temperature, with higher operating pressure, it is easier for the fluids to form hydrate. With pipeline and riser production system, if the flow conditions are such that severe slugging occurs, the slugs will be proportional to the riser length (Boyun and others, 2005). The longer the riser, the longer the severe slugs.

Effective management of the system thermal properties is crucial to the success of a deep water field development.

To ensure fit-for-purpose design, all available technologies are considered and, in general, for less stringent requirements, wet insulation on rigid pipeline, or insulated flexible flow lines can be used. However, for more stringent specifications a dry environment will be necessary to provide the required insulation performance.

As new developments are moving progressively into deeper water, where the ambient temperature at the seabed becomes even lower, successful operation becomes more heavily dependent on the thermal management strategy employed.

Thermal management strategy and insulation generally include the following; Overall Heat Transfer Coefficient, Steady State Heat Transfer and Transient Heat Transfer.

II. Problem Formulation and Solution

Oil field flow lines are insulated mainly to conserve heat. The need to keep the product in flow line at temperature higher than the ambient temperature could exist for reasons including the followings:

- Preventing formation of gas hydrate
- Preventing formation of gas hydrate, wax or asphaltenes
- Enhancing product flow properties
- Increasing cool down time after shutting down

In liquefied-gas pipelines, such as those for liquefied natural gas, insulation is required to maintain the cold temperature of the gas to keep it in liquid state.

Polypropylene, Polyethylene and Polyurethane are three base materials widely used in the petroleum industry for pipeline insulation. Depending on applications, these base materials are used in different forms, resulting to different overall conductivities. A three layer polypropylene applied to pipe surface has conductivity of 0,225 W/(m-°C), while a four layer polypropylene has conductivity of 0.173 W/(m-°C). Solid polypropylene has higher conductivity than polypropylene foam. Polymer syntactic polyurethane has conductivity of 0.121 W/(m-°C) while glass syntactic polyurethane has conductivity of 0.156 W/(m-°C). These materials have lower conductivities in dry conditions such as in pipe in pipe (PIP) applications.

Because of their low thermal conductivities, more and more polyurethane foam is used in deep water flow lines applications. Physical properties of polyurethane foam include density, compressive strength, thermal conductivity, closed-cell content, leachable halides, flammability, tensile strength, tensile modulus and water absorption. Typical values of these properties are available from literature (Guo and others, 2005).

The requirements for flow lines insulation vary from field to field. Flow assurance analysis need to be perform to determine the minimum requirement for a given field. These analyses include the following:

- Flash analysis of the production fluid to determine the hydrate formation temperature in the range of operating pressure.
- Global thermal hydraulic analysis to determine the required overall heat transfer coefficient at each location in the flow line.
- Local heat transfer analysis to determine the type and thickness of insulation to be used at the location.
- Local transient heat transfer analysis at special location along the flow line to develop cool down curves and time to the critical minimum allowable temperature at each location.

Formulation of the governing equations and solution to the heat transfer problem in deepwater flow lines under different conditions are given in the Appendix. The resultant equations are summarized in this section.

The internal temperature profile under steady fluid flow condition is expressed as:

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+C)}\right] \quad (1.10)$$

Where the constant groups are defined as:

$$\alpha = \frac{2\pi Rk}{v\rho C_p sA} \qquad (1.20)$$
$$\beta = \alpha G cos\theta \qquad (1.30)$$
$$\gamma = -\alpha T_{f,0} \qquad (1.40)$$
$$C = -\frac{1}{\alpha} ln(\beta - \alpha^2 T_{f,s} - \alpha\gamma) \qquad (1.50)$$

where T_f is the temperature inside the pipe, L is the longitudinal distance from the fluid entry point, R is inner radius of insulation layer, k is the thermal conductivity of the insulation material, v is the average flow velocity of fluid in the pipe, ρ is the fluid density, C_p is the heat capacity of fluid at constant pressure, s is the thickness of insulation layer, A is the inner cross sectional area of pipe, G is the principal thermal gradient outside the insulation, θ is the angle between the principal thermal gradient and the pipe orientation, $T_{f,0}$ is the temperature of outer medium at the fluid entry location and $T_{f,s}$ is the temperature of the fluid at fluid entry point.

The rate of heat transfer across the insulation layer over the whole length of the flow line is expressed as:

$$q = \frac{2\pi Rk}{s}\left(T_{f,0}L - \frac{Gcos\theta}{2}L^2 - \frac{1}{\alpha^2}\left\{(\beta - \alpha\gamma)L - \frac{\alpha\beta}{2}L^2 + \frac{1}{\alpha}\left[e^{-\alpha(L+C)} - e^{-\alpha C}\right]\right\}\right) \quad (1.60)$$

Where q is the rate of heat transfer (heat loss).
The internal temperature profile after starting up a fluid flow is expressed as follows:

$$T_f = \frac{1}{\alpha^2}\{\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha[L+f(L-vt)]}\} \quad (1.70)$$

Where the f is given by:

$$f(L-vt) = -(L-vt) - \frac{1}{\alpha} ln\{\beta - \alpha\beta(L-vt) - \alpha\gamma - \alpha^2[T_{f,s} - Gcos\theta(L-vt)]\} \quad (1.80)$$

And t is time.
Suppose after increasing or decreasing the flow rate, the fluid has a new velocity v' in the flow line. The internal temperature profile is expressed as follows:

$$T_f = \frac{1}{\alpha'^2}\left\{\beta' - \alpha'\beta' L - \alpha'\gamma' - e^{-\alpha'[L+f(L-v't)]}\right\} \quad (1.90)$$

Where

$$\alpha = \frac{2\pi Rk}{v'\rho C_p sA} \qquad (2.00)$$
$$\beta' = \alpha' G cos\theta \qquad (2.10)$$
$$\gamma' = -\alpha' T_{f,0} \qquad (2.20)$$

And the function f is given by:

$$f(L-v't) = -(L-v't) - \frac{1}{\alpha'} ln\left\{\beta' - \alpha'\beta'^{(L-v't)} - \alpha'\gamma' - \left(\frac{\alpha'}{\alpha}\right)^2\left[\beta - \alpha\beta(L-v't) - \alpha\gamma - e^{-\alpha\{(L-v't)+C\}}\right]\right\} \quad (2.30)$$

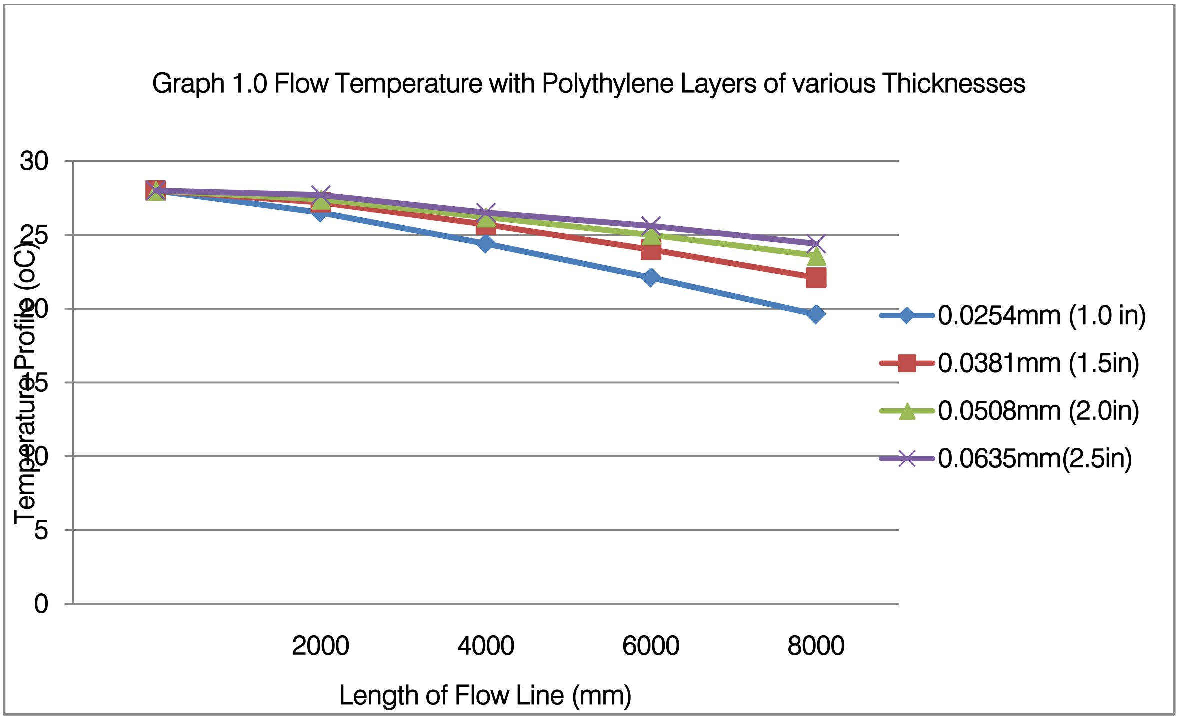
III. Result and Discussion

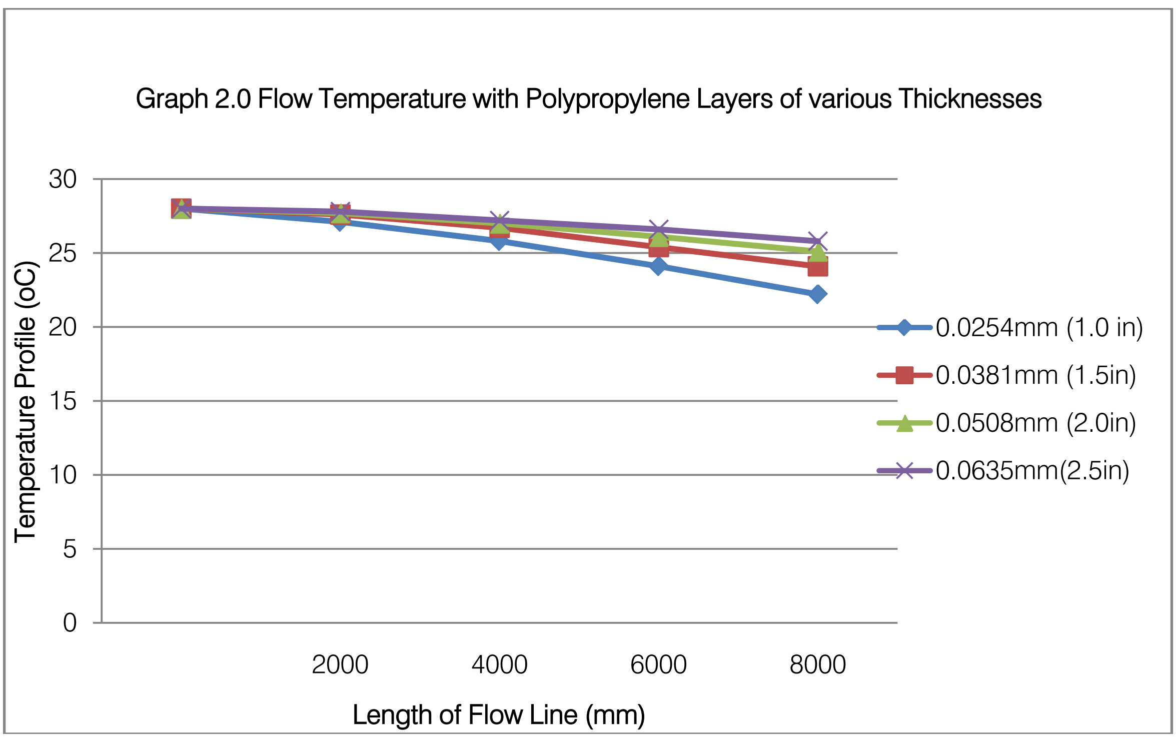
The mathematical model presented in chapter two is used to design flow line deep water. The main goal of the analysis was to select an appropriate insulation layer thickness and material. Design basis for the flow line is presented in Appendix B. The design criterion is to ensure that the temperature at any point on the flow line does not drop to below 25°C, as required by flow assurance. Insulation materials considered for this design are Polyethylene, Polypropylene and Polyurethane.

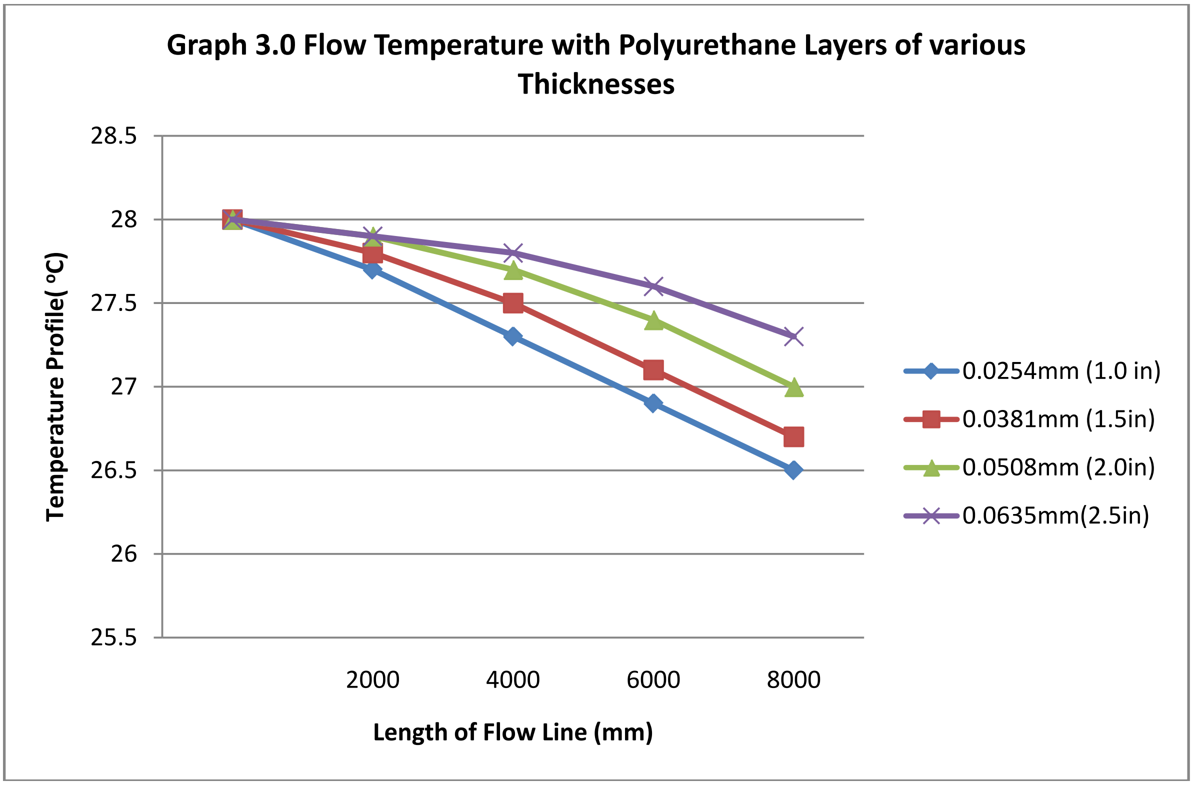
A Polyethylene layer of 0.0254mm (1 in) was first considered and later increased to 0.0381mm (1.5 in), 0.0508mm (2.0 in) and 0.0635mm (2.5 in). Graph 1 present's steady state flow temperature profile calculated using equation 1.10 with four insulation thicknesses. It shows that even a Polyethylene of 0.0635mm (2.5 in) thick will give a flow line temperature lower than 25°C, therefore, Polyethylene should not be considered for this design.

A Polypropylene layer of 0.0254mm (1 in) was then considered and later increased to 0.0381mm (1.5 in), 0.0508mm (2.0 in) and 0.0635mm (2.5 in). Graph 2 present's steady state flow temperature profile calculated using equation 1.10. It shows that a Polypropylene layer of 0.0508mm (2.0 in) thick and above will give a flow line temperature higher than 25°C.

Graph 3 present's steady state flow temperature profile calculated using Polyurethane layer of four thicknesses. It shows that a Polyurethane layer of 0.0381mm (1.5 in) thick is required to keep the flow line temperature higher than 25°C under normal operating conditions. Therefore, either a Polypropylene layer of 0.0508mm (2.0 in) thick and above or Polyurethane layer of 0.0381mm (1.5 in) thick should be chosen for insulation of the flow line. Cost analyses can justify one of the options, which is beyond the scope of this work.


Graph 1.0 Flow Temperature with Polythylene Layers of various Thicknesses
Temperature Profile (oC)
30
25
20
15
10
5
0
2000
4000
6000
8000
Length of Flow Line (mm)
0.0254mm (1.0 in)
0.0381mm (1.5in)
0.0508mm (2.0in)
0.0635mm(2.5in)


Graph 2.0 Flow Temperature with Polypropylene Layers of various Thicknesses
Temperature Profile (oC)
30
25
20
15
10
5
0
2000
4000
6000
8000
Length of Flow Line (mm)
0.0254mm (1.0 in)
0.0381mm (1.5in)
0.0508mm (2.0in)
0.0635mm(2.5in)



IV. CONCLUSION

Thermal insulation is a critical element in the design and operation of flow lines in deep waters due to a combination of low temperatures and high pressure, as result of these; stringent requirement should be taken for optimal insulation. A spreadsheet model has been proposed for the design of deep water flow lines insulation thickness. For optimal insulation thickness to be achieved in the design of deep water flow line, comparison should be made among different insulation materials with various thicknesses. The temperature profile should be plotted against the flow line length to know where there is possibility of hydrate formation or wax appearance region.

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APPENDIX A

Steady and Transient Solutions for Flow Line Temperature

1. Assumptions

The following assumptions are made in model formulation:

1) friction-induced heat is negligible
2) Heat transfer in the radial direction is fully controlled by the insulation fluid
3) Specific heat of fluid is constant

2. Governing Equation

Consider the heat flow during a time period of Δt_f. Heat balance is given by

$$q_{in} - q_{out} - q_R = q_{acc} \quad (A.1)$$

where

q_{in} = heat energy brought into the pipe element by fluid due to convection, J
q_{out} = heat energy carried away from the pipe element by fluid due to convection, J
q_R = heat energy transferred through the insulation layer due to conduction, J
q_{acc} = heat energy accumulation in the pipe element, J
These terms can be further formulated as

$$q_{in} = \rho_f C_p v A_f T_{f,L} \Delta t_f \quad (A.2)$$
$$q_{out} = \rho_f C_p v A_f T_{f,L+\Delta L} \Delta t_f \quad (A.3)$$
$$q_R = 2\pi R_n k_n \Delta L \frac{\partial T_f}{\partial r} \Delta t_f \quad (A.4)$$
$$q_{acc} = \rho_f C_p A_f \Delta L \Delta \bar{T}_f \quad (A.5)$$

where

ρ_f = fluid density, Kg/m^3
C_p = specific heat at constant pressure, J/kg-°C
v = the average flow velocity of fluid in the pipe, m/s
A_f = cross-sectional area of pipe open for fluid flow, m^2
$T_{f,L}$ = temperature of the flowing-in fluid, °C
Δt_f = flow time, s
$T_{f,L+\Delta L}$ = temperature of the flowing-out fluid, °C
s = insulation layer thickness
R_n = inner-radius of insulation layer, m
k_n = thermal conductivity of the insulation layer, W/m- °C
ΔL = length of the pipe segment, m
$\frac{\partial T_f}{\partial r}$ = radial-temperature gradient in the insulation layer, °C/m
$\Delta \bar{T}_f$ = the average temperature increase of fluid in the pipe segment, °C
Substituting Equations (A.2) through (A.5) into Equation (A.1) gives

Substituting Equations (A.2) through (A.5) into Equation (A.1) gives

$$\rho_f C_p v A_f T_{f,L} \Delta t_f - \rho_f C_p v A_f T_{f,L+\Delta L} \Delta t_f - 2\pi R_n k_n \Delta L \frac{\partial T_f}{\partial r} \Delta t_f = \rho_f C_p A_f \Delta L \Delta \bar{T}_f \quad (A.6)$$

$$\rho_f C_p v A_f \Delta t_f \left(T_{f,L} - T_{f,L+\Delta L}\right) - 2\pi R_n k_n \Delta L \frac{\partial T_f}{\partial r} \Delta t_f = \rho_f C_p A_f \Delta L \Delta \bar{T}_f \quad (A.7)$$

Dividing all the terms of this equation by $\Delta L \Delta t_f$ yields

$$\rho_f C_p v A_f \frac{\left(T_{f,L} - T_{f,L+\Delta L}\right)}{\Delta L} - 2\pi R_n k_n \frac{\partial T_f}{\partial r} = \rho_f C_p A_f \frac{\Delta \bar{T}_f}{\Delta t_f} \quad (A.8)$$

For infinitesimal of ΔL and Δt_f this equation becomes

$$v \frac{\partial T_f}{\partial L} + \frac{\partial \bar{T}_f}{\partial t_f} = -\frac{2\pi R_n k_n}{\rho_f C_p A_f} \frac{\partial T_f}{\partial r} \quad (A.9)$$

The radial-temperature gradient in the insulation layer can be formulated as

$$\frac{\partial T_f}{\partial r} = \frac{T_{f,L} - \left(T_{f,0} - G cos(\theta) L\right)}{s} \quad (A.10)$$

where

$T_{f,0}$ = Temperature of the medium outside the insulation layer at $L = 0$, ℃
G = Geothermal gradient, ℃$/m$
θ = Inclination time, degree
s = Thickness of the insulation layer, m
Substituting Equation (A.10) into Equation (A.9) yields

$$v \frac{\partial T_f}{\partial L} + \frac{\partial \bar{T}_f}{\partial t_f} = a T_f + bL + c \quad (A.11)$$

where

$$a = -\frac{2\pi R_n k_n}{\rho_f C_p s A_f} \quad (A.12)$$
$$b = a G cos(\theta) \quad (A.13)$$
$$c = -a T_{f,0} \quad (A.14)$$

3. Solutions

Three solutions are sought in this study: Solution A: Steady flow; Solution B: Transient flow with static fluid as the initial condition; and Solution C: Transient flow with steady flow as the initial condition

Solution A gives temperature profile during normal operation conditions; Solution B simulates temperature change during a start-up process; and Solution C yields temperature trend during a shut-down process.

4. Steady Heat Transfer

If the mass flow rate is maintained for a significantly long time, a steady heat transfer condition between the system and its surroundings is expected. Under steady flow conditions, the temperature at any point in the system is time-independent. Therefore,

Equation (A.11) becomes

$$v\frac{\partial T_f}{\partial L} = aT_f + bL \qquad (A.15)$$

This equation can be solved with boundary condition

$$T = T_{f,s} \ at \ L \qquad (A.16)$$

To simplify the solution, Equation (A.15) is rearranged to be

$$\frac{\partial T_f}{\partial L} + \alpha T_f + \beta L + \gamma = 0 \qquad (A.17)$$

where

$$\alpha = -\frac{a}{v} \qquad (A.18)$$

$$\beta = -\frac{b}{v} \qquad (A.19)$$

$$\gamma = -\frac{c}{v} \qquad (A.20)$$

Let

$$u = \alpha T_f + \beta L + \gamma \qquad (A.21)$$

Then

$$T_f = \frac{u - \beta L - \gamma}{\alpha} \qquad (A.22)$$

and

$$\frac{dT_f}{dL} = \frac{1}{\alpha}\frac{du}{dL} - \frac{\beta}{\alpha} \qquad (A.23)$$

Substituting Equations (A.22) and (A.23) into Equation (A.17) gives

$$\frac{1}{\alpha}\frac{du}{dL} - \frac{\beta}{\alpha} + u = 0 \qquad (A.24)$$

Integration of this equation with the method of separation of variables yields

$$-\frac{1}{\alpha}\ln(\beta - \alpha u) = L + C \qquad (A.25)$$

where C is a constant of integration. Substituting Equation (A.21) into Equation (A.25) and rearranging the latter result in

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+C)}\right] \quad (A.26)$$

Applying boundary condition (A.16) to Equation (A.26) gives the expression for the integration constant

$$C = -\frac{1}{\alpha}\ln\left(\beta - \alpha^2 T_{f,s} - \alpha\gamma\right) \qquad (A.27)$$

5. Transient Heat Transfer during Starting-Up

The temperature profile along the flow line during the starting-up process can be obtained by solving Equation (A.11) with the method of characteristics, subject to the initial condition

$$T_f = T_{f,0} - Gcos(\theta)L \quad at \ L = 0 \qquad (A.28)$$

Consider a family of curves defined by the equation

$$dt_f = \frac{dL}{v} = \frac{dT_f}{aT + bL + c} \qquad (A.29)$$

The characteristics are

$$L = vt_f + K \qquad (A.30)$$

We also have from Equation (A.29)

$$\frac{dT_f}{dL} = \frac{aT_f + bL + c}{v} \qquad (A.31)$$

Using notations (A.18), (A.19), and (A.20), Equation (A.31) becomes

$$\frac{dT_f}{dL} + \alpha T_f + \beta L + \gamma = 0 \qquad (A.32)$$

which is exactly Equation (A.17). Its solution is the same as Equation (A.26), i.e.,

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+A)}\right] \qquad (A.33)$$

where A is an arbitrary constant of integration. This constant is different on each characteristic curve. Further, each characteristic curve has a different value of K. Hence, as K varies, A varies and we may write $A = f(K)$, where f is an arbitrary function to be determined. Writing $A = f(K)$ in Equation (A.33) yields

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+f(K))}\right] \qquad (A.34)$$

Eliminating K using Equation (A.30), gives:

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha\left[L+f(L-vt_f)\right]}\right] \quad (A.35)$$

Now applying the initial condition (A.28) gives

$$T_{f,0} - Gcos(\theta)L \quad = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha[L+f(L)]}\right](A.36)$$

which gives

$$f(L) = -L - \frac{1}{\alpha}ln\left[\beta - \alpha\beta L - \alpha\gamma - \alpha^2\left(T_{f,0} - Gcos(\theta)L\right)\right](A.37)$$

Therefore,

$$f(L - vt_f) = -(L - vt_f) - \frac{1}{\alpha}ln\left[\beta - \alpha\beta(L - vt_f) - \alpha\gamma - \alpha^2\left(T_0 - Gcos(\theta)(L - vt_f)\right)\right] \ (A.38)$$

Substituting Equation (A.38) into Equation (A.35) results in the solution to Equation (A.11) subject to the initial condition (A.28). This solution is valid for $L - vt_f > 0$. For points at which $L - vt_f < 0$, $L - vt_f = 0$ should be used.

6. Transient Heat Transfer during a Flow Rate Change

The temperature trend along the flow line during a flow rate change (shutting-down is a special case) process can be obtained by solving Equation (A.11) with a new velocity v' ' corresponding to a new flow rate. The general solution is still given by Equation (A.35) with new parameters corresponding to the low velocity, i.e.

$$T_f = \frac{1}{\alpha'^2}\left[\beta' - \alpha'\beta' L - \alpha'\gamma' - e^{-\alpha'[L+f(L-v't_f)]}\right] \quad (A.39)$$

Where

$$\alpha' = -\frac{a}{v'} \quad (A.40)$$

$$\beta' = -\frac{b}{v'} \quad (A.41)$$

$$\gamma' = -\frac{c}{v'} \quad (A.42)$$

The initial condition is defined by Equation (A.26), i.e.,

$$T_f = \frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+C)}\right] \; at \; t_f = 0 \quad (A.43)$$

where the constant C is given by Equation (A.27).

Now applying the initial condition (A.43) to Equation (A.39) gives

$$\frac{1}{\alpha^2}\left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+C)}\right] = \frac{1}{\alpha'^2}\left[\beta' - \alpha'\beta' L - \alpha'\gamma' - e^{-\alpha'[L+f(L)]}\right] \quad (A.44)$$

which yields

$$f(L) = -L - \frac{1}{\alpha'} ln\left\{\beta' - \alpha'\beta' L - \alpha'\gamma' - \left(\frac{\alpha'}{\alpha}\right)^2 \left[\beta - \alpha\beta L - \alpha\gamma - e^{-\alpha(L+C)}\right]\right\} (A.45)$$

Therefore,

$$f(L - vt_f) = -(L - vt_f) - \frac{1}{\alpha'} ln\left\{\beta' - \alpha'\beta'(L - vt_f) - \alpha'\gamma' - \left(\frac{\alpha'}{\alpha}\right)^2 \left[\beta - \alpha\beta(L - vt_f) - \alpha\gamma - e^{-\alpha[(L-vt_f)+C]}\right]\right\} \quad (A.45)$$

Substituting Equation (A.46) into Equation (A.39) results in the solution to Equation (A.11) subject to the initial condition (A.43).

APPENDIX B

DESIGN INSULATION OF A DEEP WATER FLOW LINE			
DESIGN EXAMPLE: GAS FLOW LINE			
User Input			
Description	Symbol	Value	Units
Longitudinal distance from the fluid entry poin	L	8047	M
Outer diameter of pipe	D_o	0.2032	M
Wall thickness	t	0.00635	M
Fluid density	ρ_f	881	kg/m^3
Fluid specific heat at constant pressure	Cp	2012	J/kg-°C
Average external temperature	T_o	10	°C
Fluid temperature at entry point	T_s	28	°C
Fluid flow rate	Q	62000000	m^3/d
Inner radius of insulation	R	0.1016	M
Thermal conductivity of insulation material	k	0.35	W/m-°C
Average flow velocity of fluid	v	3.228304	m/s
Inner cross sectional area of pipe	A	0.032429	m^2

Calculated Steady State Flow Temperature Profile with a Polyethylene layers of various thicknesses								
Calculated Temperature Profile with a Polyethylene layer of 0.0254m								
T	28	26.6	24.4	22.1	19.6			
L	0	2000	4000	6000	8000			
Calculated Temperature Profile with a Polyethylene layer of 0.0381m								
T	28	27.2	25.7	24	22.1			
L	0	2000	4000	6000	8000			
Calculated Temperature Profile with a Polyethylene layer of 0.0508m								

T	28	27.4	26.2	25	23.6
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0635m					
T	28	27.7	26.5	25.6	24.4
L	0	2000	4000	6000	8000
Calculated Steady State Flow Temperature Profile with a Polypropylene layers of various thicknesses					
Calculated Temperature Profile with a Polyethylene layer of 0.0254m					
T	28	27.1	25.8	24.1	22.2
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0381m					
T	28	27.6	26.7	25.4	24.1
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0508m					
T	28	27.7	27	26.1	25.1
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0635m					
T	28	27.8	27.2	26.6	25.8
L	0	2000	4000	6000	8000
Calculated Steady State Flow Temperature Profile with a Polyurethane layer of various thicknesses					
Calculated Temperature Profile with a Polyethylene layer of 0.0254m					
T	28	27.7	27.3	26.9	26.5
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0381m					
T	28	27.8	27.5	27.1	26.7
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0508m					
T	28	27.9	27.7	27.4	27.0
L	0	2000	4000	6000	8000
Calculated Temperature Profile with a Polyethylene layer of 0.0635m					
T	28	27.9	27.8	27.6	27.3
L	0	2000	4000	6000	8000

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Design and Analysis of Circular Ring Microstrip Antenna

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Abstract- Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM^{11}) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM^{12} resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM_{1m} modes (m odd), and a good radiator for TM_{1m} modes (m even) [8]. A circular ring microstrip antenna is designed for TM_{11} mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth.

Keywords: Microstrip antennas (MSAs), Microwave Monolithic Integrated Circuits (MMIC),Wireless Local Area Networks (WLANs), Circular Ring Microstrip Antenna (CRMSA),Voltage Standing Wave Ratio (VSWR).

Classification: GJRE-F Classification (FOR): 090609

DESIGN AND ANALYSIS OF CIRCULAR RING MICRO STRIP ANTENNA

Strictly as per the compliance and regulations of:

Design and Analysis of Circular Ring Microstrip Antenna

Rajesh Kumar[1], Dr. D. C. Dhubkarya[2]

Abstract-Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM^{11}) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM^{12} resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM_{1m} modes (m odd), and a good radiator for TM_{1m} modes (m even) [8]. A circular ring microstrip antenna is designed for TM_{11} mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth.

Keywords: Microstrip antennas (MSAs), Microwave Monolithic Integrated Circuits (MMIC), Wireless Local Area Networks (WLANs), Circular Ring Microstrip Antenna (CRMSA), Voltage Standing Wave Ratio (VSWR).

I. Introduction

Microstrip antennas, often referred to as patch antennas consists of a very thin metallic patch (usually gold or copper) placed a small fraction of a wavelength above a conducting ground plane, separated by a dielectric substrate. The radiating patch can be of any planar geometry e.g. rectangle, circle, square, thin strip (dipole), elliptical, ring, circular ring, disc sector and triangular. The radiating elements and the feed lines are usually photo etched on the dielectric substrate.

Microstrip antennas have some advantages such as light weight, low cost etc. and some disadvantages such as low bandwidth and efficiency. However there are different methods by which their efficiency and bandwidth may be improved. These antennas are low-profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with microwave monolithic integrated circuits (MMIC) designs, and when particular patch shape and mode are selected they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, microstrip antennas with variable resonant frequency, impedance, polarization, and pattern can be designed [4].

The microstrip antennas find application in high-performance spacecraft, aircraft, missile and satellite, mobile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, and low profile antennas are required. Presently, there are many government and commercial applications, such as mobile radio and wireless communications that have similar specifications where micro strip antennas can be used. They are also used in Wireless Local Area Networks (WLANs) to provide short range high-speed data connections between mobile devices and wireless access points.

The annular-ring structure was first studied by Bergman and Schultz in 1955 as a travelling wave antenna. It has also been used as a resonator and as a radiator in medical applications [3]. Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM11) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM12 resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM1m modes (m odd), and a good radiator for TM1m modes (m even) [8].

In this paper a circular ring micro strip antenna is designed for TM11 mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth. Fig.1. shows a circular ring microstip antenna.

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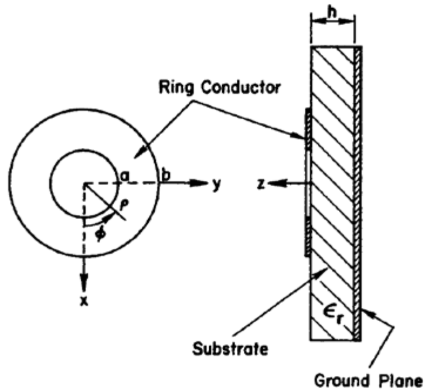

Fig.1. A circular ring microstip antenna [8]

II. Analytical Model

For designing the proposed antenna, cavity model analysis is used. The cavity model of the ring is obtained by replacing its peripheries with magnetic walls. Because there is no variation of the fields along the z direction for thin substrates, the modes are designated as TM_{nm} modes. With no excitation current, the wave equation for electrical field can be written as-

$$(\nabla^2 + k^2)\vec{E} = 0 \qquad (1)$$

Where

$$k = 2\pi\sqrt{\varepsilon_r/\lambda_0} \qquad (2)$$

The general solution for the wave equation (1) in cylindrical coordinates is given as-

$$E_z = E_0[J_n(k\rho)Y_n'(ka) - Jn'kaYnk\rho\cos n\emptyset \qquad (3)$$

and

$$H_\rho = \frac{j}{\omega\mu\rho}\frac{\partial E_z}{\partial\emptyset}, \qquad H_\emptyset = \frac{-j}{\omega\mu}\frac{\partial E_z}{\partial\rho} \qquad (4)$$

Where $J_n(.)$ and $Y_n(.)$ are the Bessel functions of the first and second kind, and of order n, respectively. The other field components are zero inside the cavity. The surface current on the lower surface of ring metallization is given by-

$$\vec{J}_S = -\hat{z}\times\vec{H} = -\hat{\emptyset}H_\rho + \hat{\rho}H_\emptyset \qquad (5)$$

Or

$$J_\emptyset = \frac{jn E_0}{\omega\mu\rho}[J_n(k\rho)Y_n'(ka) - J_n'(ka)Y_n(k\rho)]\sin n\emptyset \qquad (6a)$$

$$J_\rho = \frac{-jn E_0}{\omega\mu}[J_n'(k\rho)Y_n'(ka) - Jn'kaYn'k\rho\cos n\emptyset \qquad (6b)$$

The radial component of the surface current must vanish along the edges at $\rho = a$ and $\rho = b$ to satisfy the magnetic wall boundary conditions. This gives

$$J_\rho(\rho = b) = H_\emptyset(\rho = b) = 0 \qquad (7)$$

Application of this boundary condition leads to the well- known characteristic equation for the resonant modes:

$$J_n'(kb)Y_n'(ka) - J_n'(ka)Y_n'(kb) = 0 \qquad (8)$$

For the given values of a, b, ε_r and n, the frequency is varied and the roots of Equation (8) are determined. These roots are denoted by k_{nm} for the resonant TM_{nm} modes and form X_{nm} such that

$$X_{nm} = k_{nm}\, a \qquad (9)$$

The integer n denotes the azimuthal variation as per $\cos n\emptyset$, while the integer m represents the mth zero of Equation (8) and denotes the variation of fields across the width of the ring.

If $C = b/a$ then Equation (8) can be written as-

$$J_n'(CX_{nm})Y_n'(X_{nm}) - J_n'(X_{nm})Y_n'(CX_{nm}) = 0 \qquad (10)$$

Using zeroth-order approximation, the resonant frequency is obtained as-

$$f_{nm} = \frac{X_{nm}\, c}{2\pi a\sqrt{\varepsilon_r}} \qquad (11)$$

Where

c = velocity of light in free space
a = Inner radii of ring
ε_r = dielectric constant of substrate

In Equation (11), the effect of the fringing fields has not been considered. Thus the frequency calculated by this formula is lower than the measured value. The accuracy can be improved by using effective dielectric constant (ε_{re}).

$$f_{nm} = \frac{X_{nm}\, c}{2\pi a\sqrt{\varepsilon_{re}}} \qquad (12)$$

To determine the value of ε_{re}, the ring resonator is modeled as a microstrip line bent in a circular shape. The effect of the curvature on the resonant frequency is expected to be small provided the radius of curvature is large compared with the width of the strip conductor. The effective dielectric constant can be determined as-

$$\varepsilon_{re} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{2}(\varepsilon_r - 1)\left(1 + \frac{10h}{W}\right)^{-\frac{1}{2}} \qquad (13)$$

Where

$W = b - a$
b = Outer radii of the ring
h = thickness of dielectric

The modified values of the inner and outer radii of the ring can be determined using parallel plate waveguide model of a microstrip line and are given by-

Where W_e is the effective width of the ring and can be given by-

$$W_e(f) = W + \frac{(W_e(0) - W)}{\left[1 + (f/f_p)^2\right]} \qquad (15)$$

$$W_e(0) = 120\pi h/z_0\sqrt{\varepsilon_r} \qquad (16)$$

$$f_p = z_0/2\mu_0 h \qquad (17)$$

Where μ_0 is the permeability and z_0 is the quasi-static characteristic impedance of microstrip line of width *W*. A pair of empirical formulas for the modified radii of the ring are-

$$a_e = a - \frac{3h}{4} \quad (18a)$$

$$b_e = b + \frac{3h}{4} \quad (18b)$$

The above model gives reasonably accurate results as long as W_e is less than the mean diameter of the ring, i.e. $(a + b)$.

An approximate value of $X_{n1} = k_{n1}a$ can be obtained using the equation (19). This expression gives reasonably accurate value of k_{n1} for $n \leq 5$ and $[(b-a)/(b+a)] < 0.35$

$$X_{n1} = k_{n1}a = 2an/(a + b) \quad (19)$$

III. Design Specificatons

To design the proposed microstrip antenna, glass epoxy (quartz) dielectric material having dielectric constant (ε_r) of 4.2 and dielectric loss tangent (tanδ) of 0.0005 is selected with the substrate of height 1.6 mm. Outer to inner radius ratio (b/a) of the patch is selected as 2. The parameters calculated using cavity model are- effective dielectric constant (ε_{re}) = 3.52, inner radius (a) = 8.6 mm, outer radius (b) = 17.2 mm, width of the patch (W) = 8.6 mm.

IV. Simulation Results

IE3D v. 14.2 is used as a tool for the simulation purpose. A trial and error method is used to locate the feed point. For different location of the feed point, the return loss (RL) is compared and that feed point is selected, where the return loss is most negative (or minimum) or where the input impedance is 50 ohms for the resonant frequency. From Return Loss v/s frequency plot (RL = -24.9 dB at 2.0 GHz) and VSWR v/s frequency plot (VSWR = 1.121 at 2.0 GHz), the bandwidth of the designed circular ring microstrip antenna is found to be 21 MHz. From Magnitude v/s frequency plot, the value of antenna impedance is 49.14 Ω at frequency of 1.999 GHz which is very close to resonant frequency 2.0 GHz.

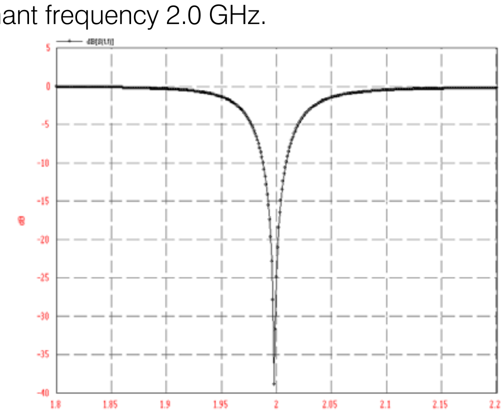

Fig.2. S-parameter plot for Return loss v/s Frequency for 1.8 2.2 GHz

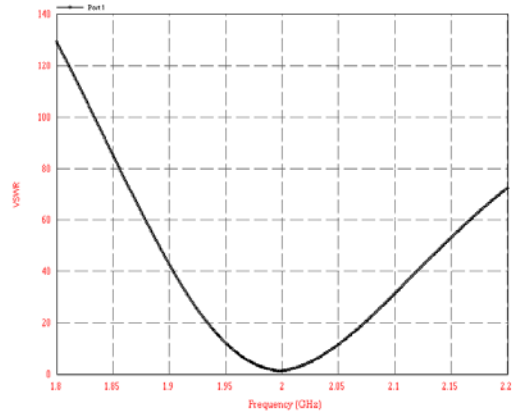

Fig.3. VSWR v/s Frequency plot for 1.8 -2.2 GHz.

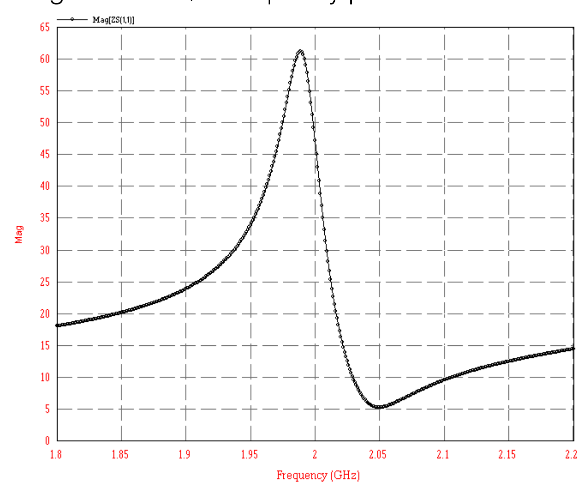

Fig.4. Magnitude v/s Frequency plot for Z Parameter for 1.8-2.2 GHz

V. Testing results

After simulation the designed antenna is fabricated with given specifications and tested on spectrum analyzer using coaxial probe feed. On testing the fabricated antenna the return loss of -13.5 dB is obtained at 1.989 GHz, which is very close to desired frequency of operation for the designed antenna i.e. (2.0 GHz). Also the bandwidth obtained is 25 MHz.

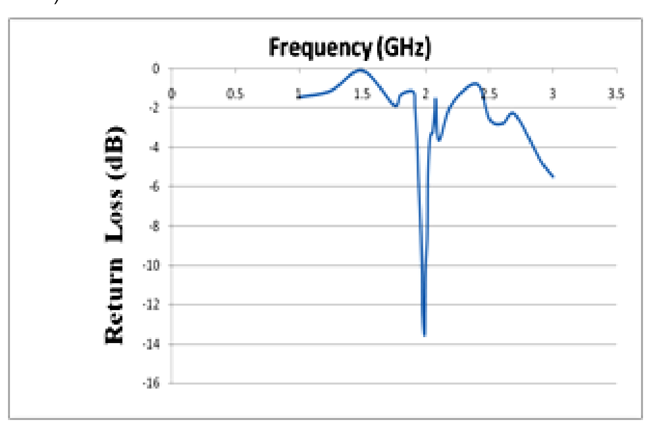

Fig.5. Return loss v/s Frequency plotted in excel based on testing results

VI. Conclusion

If we compare the simulated and tested values of designed antenna, we find that the return loss is lower than -10 dB in both the cases, for desired frequency of the designed antenna. This states that the losses are minimum during the transmission. The tested and simulated bandwidth has the ratio of 1.23, so we can say that the level of mismatch is not so high. The BW of the designed hardware was found to be small of the order of 21 MHz, which matches the theoretical background of CRMSAs operating in dominant modes. Thus it is found practically that the ring microstrip antennas have smaller dimensions at the cost of low bandwidth when operated in TM_{11} mode.

VII. Acknowledgement

The authors would like to thank Mr. Nitin Agarwal, Asst. Professor, FETRBS, and Agra for his cooperation in using IE3D for simulation of designed antenna.

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Energy Forecasting of Bangladesh in Gas Sector Using LEAP Software

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Abstract- This paper represents the first application of Long-Range Energy Alternative Planning (LEAP) software in energy forecasting of gas sector in Bangladesh. LEAP is used to take government decisions in many developed countries. In this work, at first the data on amount of gas consumption in different sectors of Bangladesh have been collected from year 1993 up-to year 2007. Then using 'Linear' and 'Exponential' time series wizard, gas consumption of these sectors has been forecasted up-to year 2020. Comparison between the results of forecasted data using aforementioned two time-series wizards have been discussed. The most acceptable forecasting model and why it wasn't used in this work have also been discussed thoroughly.

Keywords: Energy Forecast, Exponential Forecast, Linear Forecast, Logistic Forecast, Long Range Energy Alternative Planning (LEAP)

Classification: GJRE-J FOR Classification: 850103

ENERGY FORECASTING OF BANGLADESH IN GAS SECTOR USING LEAP SOFTWARE

Strictly as per the compliance and regulations of:

Energy Forecasting of Bangladesh in Gas Sector Using LEAP Software

Shahidul I. Khan[1], Asif Islam[2], Alimul Haque Khan[3]

Abstract - This paper represents the first application of Long-Range Energy Alternative Planning (LEAP) software in energy forecasting of gas sector in Bangladesh. LEAP is used to take government decisions in many developed countries. In this work, at first the data on amount of gas consumption in different sectors of Bangladesh have been collected from year 1993 up-to year 2007. Then using 'Linear' and 'Exponential' time series wizard, gas consumption of these sectors has been forecasted up-to year 2020. Comparison between the results of forecasted data using aforementioned two time-series wizards have been discussed. The most acceptable forecasting model and why it wasn't used in this work have also been discussed thoroughly.

Keyword: Energy Forecast, Exponential Forecast, Linear Forecast, Logistic Forecast, Long Range Energy Alternative Planning (LEAP)

I. Introduction

LEAP – Long-range Energy Alternative Planning is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute (SEI). LEAP has been adopted by hundreds of organizations in more than 150 countries worldwide. Its users include government agencies, academics, non-governmental organizations, consulting companies and energy utilities. It has been used at many different scales ranging from cities and states to national, regional and global applications. The United Nations recently announced that more than 85 countries have chosen to use LEAP as part of their commitment to report to the U.N. Framework Convention on Climate Change (UNFCCC) [1].

II. Gas Sector of Bangladesh

Energy consumption in Bangladesh constitutes only 0.1 per cent of total world energy consumption. Consumption of commercial energy makes up about half of total energy consumption, somewhat less than other South Asian countries, but its absolute level is very low even in comparison with the low South Asian standard. The two most important energy intensive sectors are transport and industry, accounting for around 50% and 43% of total commercial energy use in the country.

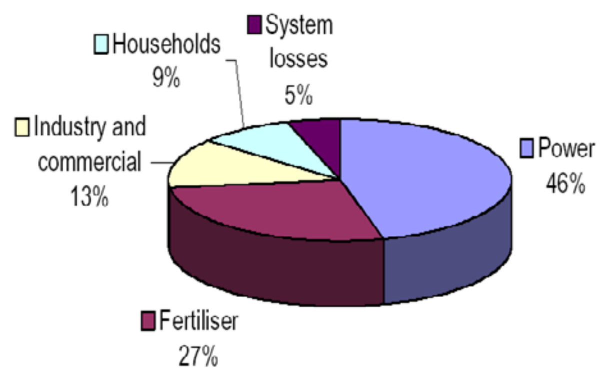

Figure 1: Gas Consumption in Bangladesh in 1998[2]

Before the discovery of significant quantities of natural gas, energy supply depended on limited domestic hydroelectricity and coal or fuel-driven power generation based on imports. Gas is currently the only indigenous non-renewable energy resource in the country that is produced and consumed in significant quantities [3]. Gas production is concentrated in the hands of four suppliers: two of them are international oil companies and two are national companies. The International Oil Companies (IOC) produce a quarter of total production – Shell produces 16% of the total while Unocal accounts for the remaining 9%. The rest is produced by two Petrobangla firms. Total production has on average increased by 7.1% per year during the last decade and daily production is 900 million cubic feet. Arrangements with international oil companies are regulated through production sharing agreements. The IOCs cover all the costs of exploration and production.

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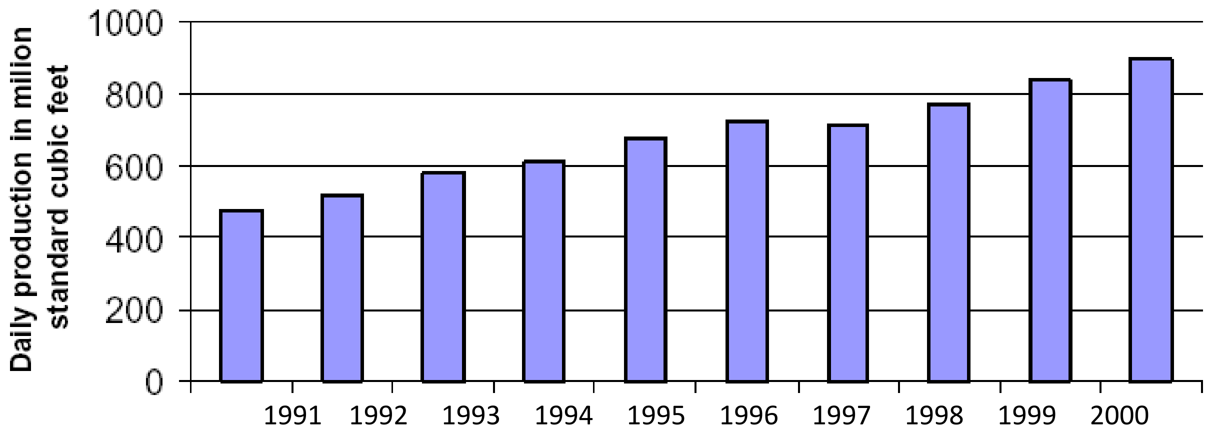

Figure 2: Yearly Gas Production in Bangladesh [2]

III. ENERGY FORECASTING

A state energy forecast is a measurement and estimate of historic, current and projected patterns of energy supply and demand within a state. The baseline or Business As Usual (BAU) forecast illustrates what state energy use will look like in the absence of additional policies beyond what is already planned.

There are six steps involved in creating a baseline forecast:

1. Define objectives and constraints of the forecast.
2. Compile historical energy consumption and generation data into a baseline profile.
3. Choose method to forecast the energy baseline.
4. Develop or review assumptions.
5. Apply the method.
6. Evaluate forecast output

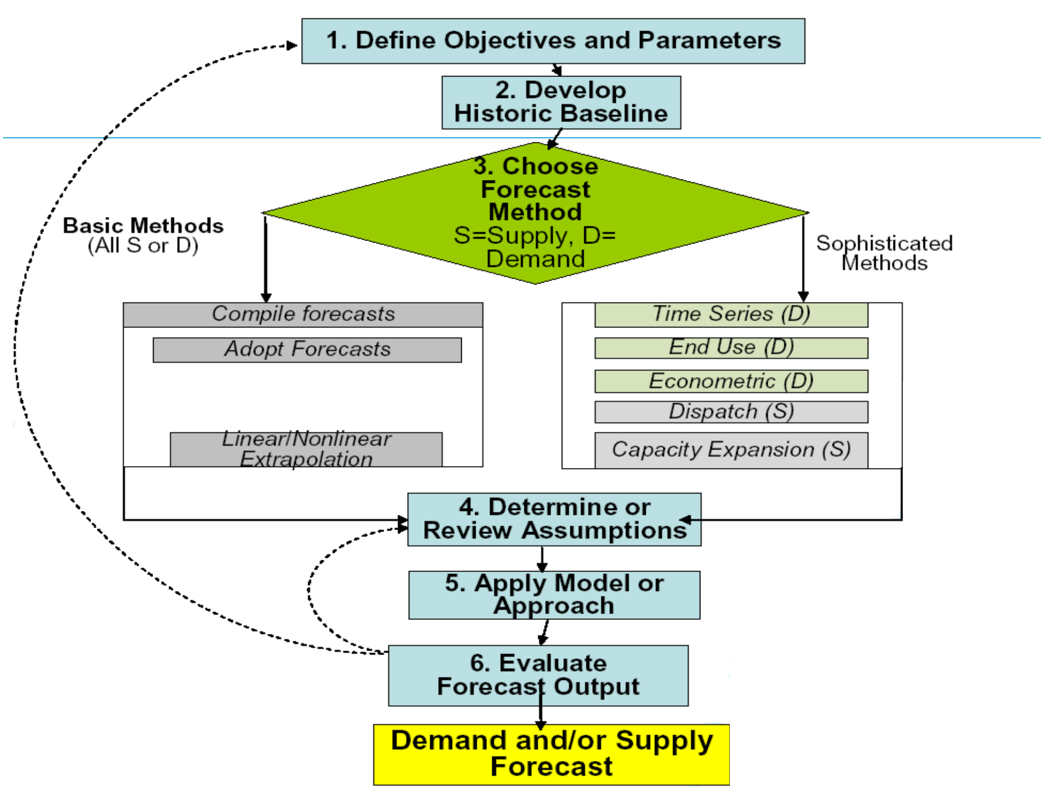

Figure 3: Flowchart Showing Steps to Forecast Energy [4]

IV. Background of LEAP

LEAP was created in 1980 for the Beijer Institute's Kenya Fuel wood Project, to provide a flexible tool for long-range integrated energy planning. It was designed by Paul Raskin, President of Energy Systems Research Group (ESRG was renamed Tellus Institute in 1990). LEAP provided a platform for structuring data, creating energy balances, projecting demand and supply scenarios, and evaluating alternative policies, the same basic goals as the current version of LEAP. Major funding was provided by Swedish SIDA, German GTZ, the Government of the Netherlands (DGIS), and US-AID [1]. The spread of the Internet in the mid-1990s allowed for much wider dissemination of LEAP. In 1991, the first major LEAP based study in an OECD country was conducted by Tellus, America's Energy Choices: An analysis of the potential for energy efficiency and renewable in the USA. In 1992, the first global energy study using LEAP was published by SEI-Boston, Towards a Fossil Free Energy. Meanwhile, studies continued throughout the developing world, including a World Bank sponsored project to integrate LEAP with an emission dispersion model for studying air quality in Beijing. By 2003, with the number of LEAP users approaching 500 with most in the developing world, a new project was launched to upgrade the support provided to these users and to foster a community among Southern energy analysts working on sustainability issues. With support from DGIS, a new web-based community called COMMEND was created, with the number of participating LEAP users growing to over 1500 in more than 130 countries by early 2006 [1].

V. LEAP Calculation Flows

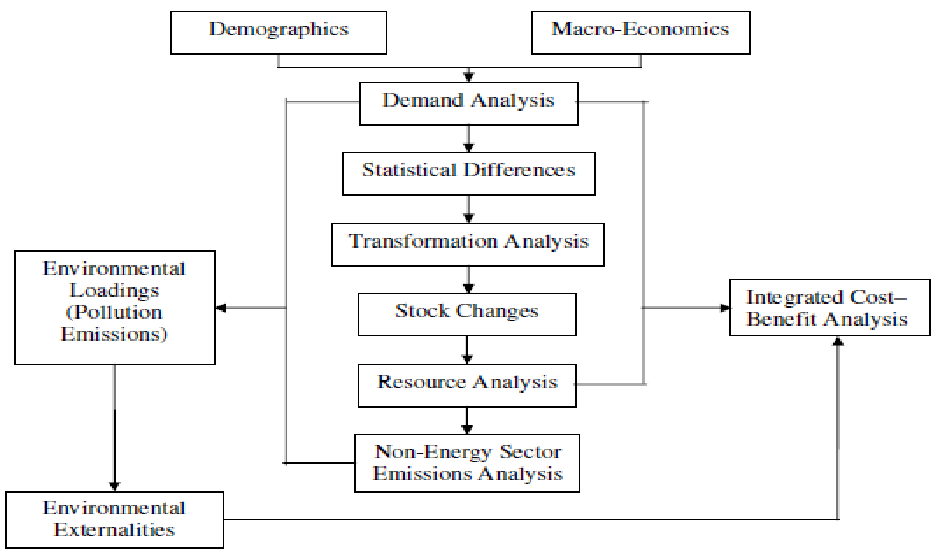

Figure 4: Flowchart Showing Data Calculation Flow in LEAP

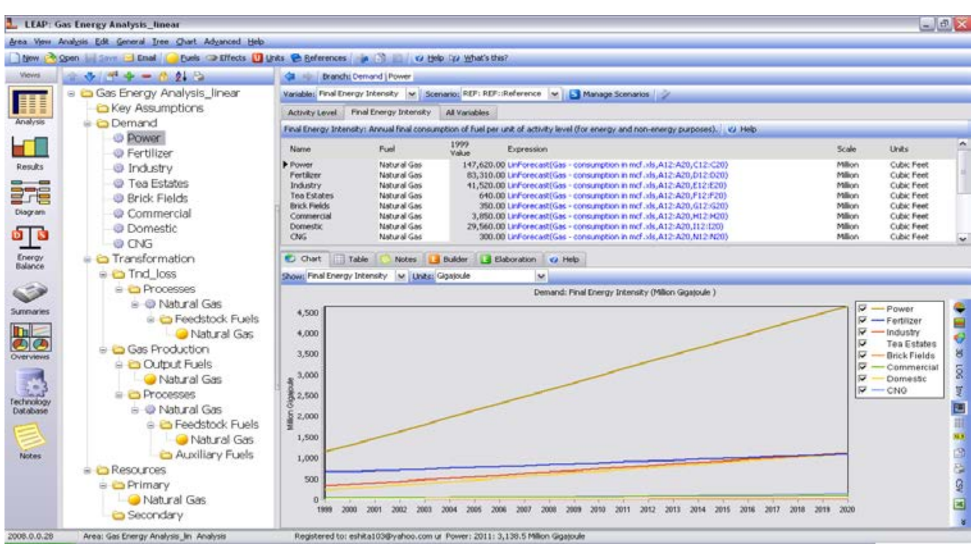

Figure 5: Analysis View of LEAP

VI. Data Requirement

For Energy Planning & Mitigation Assessment, six types of data are required [11] as input to LEAP. These are:

1) Demographic Data
2) Economic Data
3) General Energy Data
4) Demand Data
5) Transformation Data
6) Fuels Data

VII. Time-Series Wizard

There are six types of Time-Series [11] Wizard available for energy forecasting in LEAP. These are:

1) Interpolation
2) Step-Function
3) Linear Forecasting
4) Exponential Forecasting
5) Logistic Forecasting
6) Smooth-Curve

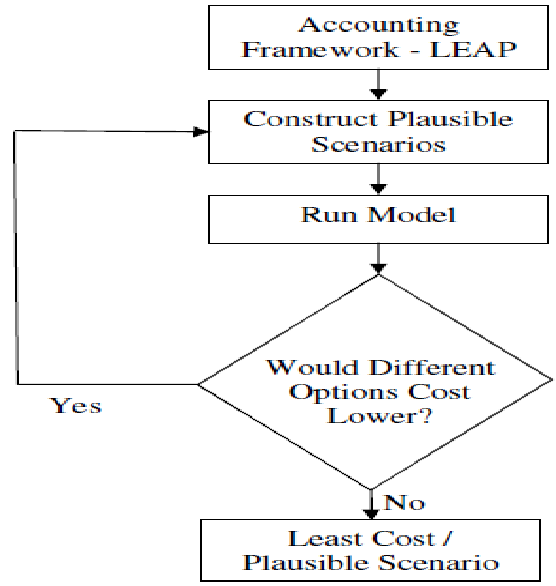

Figure 6: General Accounting Framework of LEAP

VIII. Accumulated Data

Sector-wise consumption of natural gas [5]-[10], [12]-[15] in BCF (Billion Cubic Feet)

Year	Power	Fertilizer	Industry	Tea Estates	Brick Fields	Commercial	Domestic	CNG
1993	97.3	74.5	20.26	0.70	0	2.87	15.4	0
1994	102.4	80.5	24.24	0.60	0	2.88	18.86	0
1995	110.9	90.98	27.31	0.72	0.99	3.00	20.71	0
1996	110.82	77.83	28.62	0.71	0.48	4.49	22.84	0
1997	123.55	80.07	32.32	0.74	0.39	4.61	24.89	0
1998	140.82	82.71	35.79	0.71	0.35	4.71	27.02	0
1999	147.62	83.31	41.52	0.64	0.35	3.85	29.56	0
2000	175.27	88.43	47.99	0.65	0.44	4.06	31.85	0
2001	190.03	78.78	53.56	0.72	0.53	4.25	36.74	0
2002	190.54	95.89	63.76	0.74	0.52	4.56	44.8	0.23
2003	199.4	92.8	46.59	0.82	0.12	4.83	49.22	1.94
2004	210.67	94.14	51.63	0.84	0	5.1	52.37	3.55
2005	233.6	98.91	68.98	0.8	0.1	5.5	59.45	4.5
2006	247.8	98.91	79.99	0.1	0.1	5.8	65.41	5.2
2007	268.3	107.3	86	4.5	0.1	6.3	72	5.6

IX. Analysis of Result

1. *Linear Forecast*

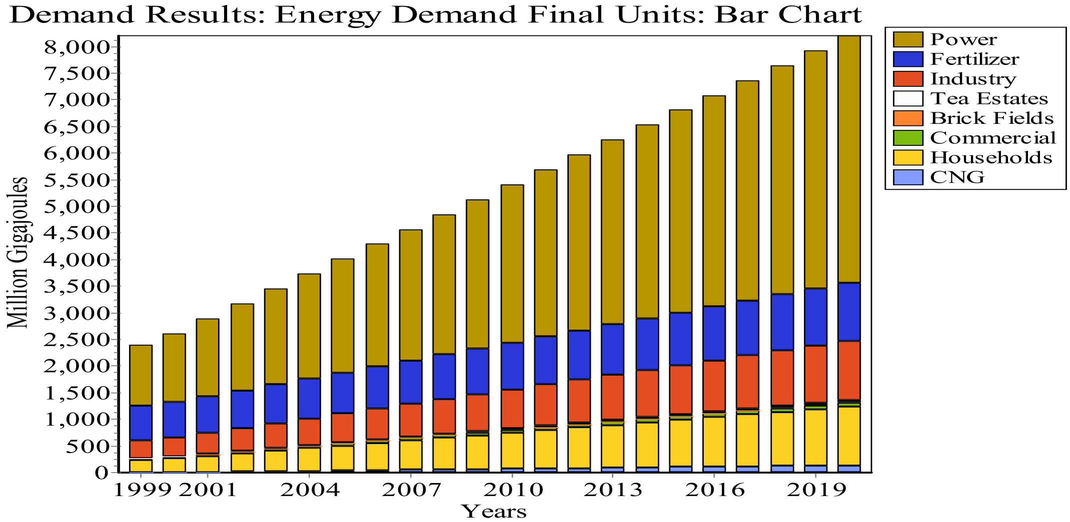

Figure 7: Demand Analysis (Linear Forecast)

Result in Tabular form (2010 - 2020)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power	2,971	3,138	3,306	3,473	3,640	3,807	3,974	4,142	4,309	4,476	4,643
Fertilizer	879	900	922	943	965	987	1,008	1,030	1,051	1,073	1,094
Industry	735	773	811	849	887	925.5	964	1,002	1,040	1,078	1,116
Tea Estates	21	23	25	27	29	30.5	32	34	36	39	40
Brick Fields	4	4.1	4.2	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
Commercial	55	57	59.5	62	64	67	69	71	734	76	78
Households	678	720	762	804	846	888	930	972	1,014	1,056	1,098
CNG	64	71	77	84	90	97	103	110	116	123	130
Total Demand (Gigajoule)	5,407	5,687	5,966	6,246	6,526	6,806	7,085	7,365	7,645	7,925	8,204
Total Demand (Bcf)	676	711	746	781	816	851	886	921	956	991	1026

2. *Exponential Forecast*

As can be seen from the records, all forecasting procedures follows exponential pattern. Even the data collected for this work, also follows exponential trends and gives better forecasted approximation of data up to 2008 if exponential increment of energy demand is assumed. But the use of exponential trend results in an abrupt situation. The demand is so high which cannot be fulfilled by the generation. Particularly the demand in the CNG sector becomes the next to the demand of the power sector by the year 2020and much greater by the year 2030, which is definitely unacceptable. That's why linear approximation is a better choice.

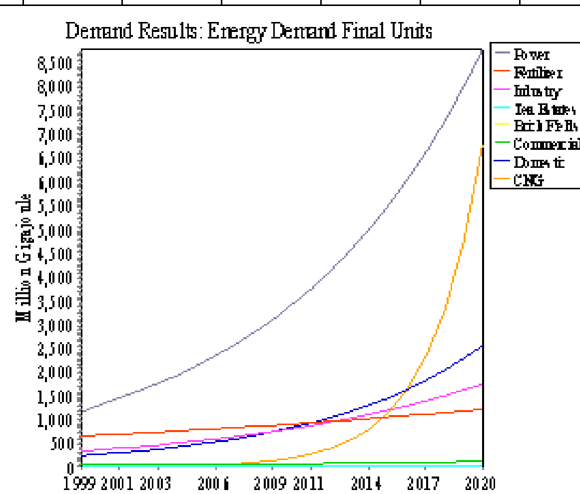

Figure 8: Demand Analysis (Exponential Forecast)

Linear vs. Exponential forecast (Year 2010)

Sectors	Linear Approximation (Giga joules)	Exponential approximation (Giga joules)
Power	4643.2	8755.8
Fertilizer	1094.5	1201.6
Industry	1115.9	1743.6
Tea Estates	39.6	11.6
Brick Fields	4.9	4.8
Commercial	78.3	107.2
Households	1098.5	2547.5
CNG	129.6	21140.2
Total	8204.5	35512.3

X. Conclusion

Among the six patterns in time-series wizard – Interpolation, Step Function, Smooth Curve, Linear Forecast, Exponential Forecast and Logistic Forecast; Logistic Forecast is the best way to achieve more accurate energy forecasting. But in case of the energy forecasting in a third world country like Bangladesh, the demand function of different economic parameters, which is the key factor of logistic forecasting, is unavailable. Rather the economic situation leaps and bounds due to unstable political scenario. That's why linear forecasting has been used in energy modeling of Bangladesh. But in stable political situation with demand functions into account, precise approximation can be made following the aforementioned guidelines.

XI. Acknowledgement

The authors would like to acknowledge Charlie Heaps (LEAP Developer and COMMEND Manager) for the software support. They are also grateful to Dr. Nurul Islam (Professor, Institute of Appropriate Technology, BUET), Dr. Jubair Bin Alam (Professor, Department of Civil Engineering, BUET), Masum Al Beruni (Chairman, WAPDA) & Dr. Ijaz Hossain (Professor, Head of Department of Chemical Engineering, BUET) for their consistent data and information source.

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Low Power High Performance SRAM Design Using VHDL

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Abstract- Data retention and leakage current are among the major area of concern in today's CMOS technology. In this paper 6T SRAM cell has been analyzed on the basis of read noise margin (RNM), write noise margin (WNM), read delay, write delay, and data retention voltage (DRV). Implementation and simulation is carried out using VHDL. The word "static" indicates that the memory retains its contents as long as power remains applied. SRAM indicates that locations in the memory can be accessed, i.e. written or since it is volatile memory and preserves data only while power is continuously applied. Each bit in SRAM is stored in four transistors that form two cross-coupled inverters. This storage cell has two stable states which are used to denote '0' and '1'. Two additional access transistors serve to control the access to a storage cell during read and write operations. It thus typically takes six MOSFETs to store one memory bit. The data retention voltage for 6T SRAM cell comes to be 252.3mV. The higher read delay is attributed to the fact that dual threshold voltage technology has been in it in the order to reduce the leakage current. Write delay has found to be 8.57 ps.

Keywords: 6T SRAM cell; VHDL; Data retention voltage; Read noise margin; Write noise margin; Intrinsic parameter fluctuation

Classification: GJRE-F FOR Classification: 090601

Strictly as per the compliance and regulations of:

Low Power High Performance SRAM Design Using VHDL

Mahendra Kumar[1], Kailash Chandra[2]

Abstract- Data retention and leakage current are among the major area of concern in today's CMOS technology. In this paper 6T SRAM cell has been analyzed on the basis of read noise margin (RNM), write noise margin (WNM), read delay, write delay, and data retention voltage (DRV). Implementation and simulation is carried out using VHDL. The word "static" indicates that the memory retains its contents as long as power remains applied. SRAM indicates that locations in the memory can be accessed, i.e. written or since it is volatile memory and preserves data only while power is continuously applied. Each bit in SRAM is stored in four transistors that form two cross-coupled inverters. This storage cell has two stable states which are used to denote '0' and '1'. Two additional access transistors serve to control the access to a storage cell during read and write operations. It thus typically takes six MOSFETs to store one memory bit. The data retention voltage for 6T SRAM cell comes to be 252.3mV. The higher read delay is attributed to the fact that dual threshold voltage technology has been in it in the order to reduce the leakage current. Write delay has found to be 8.57 ps.

Keywords- 6T SRAM cell; VHDL; Data retention voltage; Read noise margin; Write noise margin; Intrinsic parameter fluctuation.

I. Introduction

For nearly 40 years CMOS devices have been scaled down in order to achieve higher speed, performance and lower power consumption. Due to their higher speed SRAM based Cache memories and System-on-chips are commonly used. Due to device scaling there are several design challenges for nanometer SRAM design. Now we are working with very low threshold voltage and ultra– thin gate oxide due to which leakage energy consumption is getting increased. Besides this data stability during read and write operation is also getting affected. In order to obtain higher noise margin along with better of the

performance new SRAM cells have been introduced [4]. In most of these cell read and write operation are isolated to obtain higher noise margin. In large memory capacity RAM chips, active power reduction is vital to realizing low-cost, high-reliability chips is because it allows plastic temperature.

Hence, various low power circuit technologies concerning reductions in charging capacitance, operating voltage, and static current have been developed. As a result, active power has been reduced at every generation despite a fixed supply voltage, increased chip size, and improved access time.

II. Sram Cells

A SRAM cell must be designed in such a way, so that it provides a non destructive read operation and a reliable write operation. In the conventional 6T SRAM cell this condition is fulfilled by appropriately sizing all the transistors in the SRAM cell. Sizing is done according to the cell ratio (CR). Traditional SRAM cells are symmetrically composed of transistors with identical leakage and threshold characteristics.

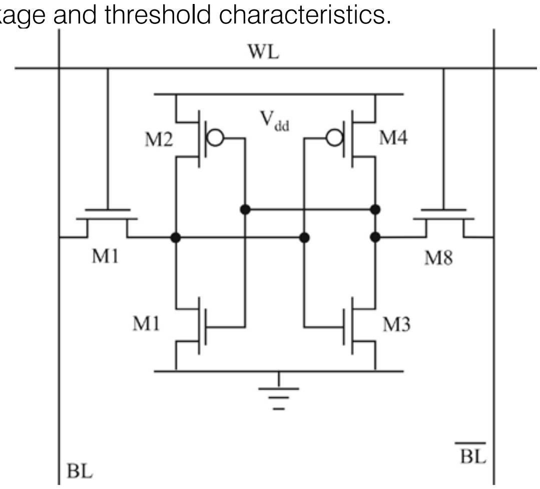

Figure 1. Six-transistor SRAM cell.

The two lines between the inverters are connected to two separate bit-lines via two n-channel pass-transistors (left and right of the cell). The gates of those transistors are driven by a word-line. The 6T SRAM cell has a differential read operation. This means that both the stored value and its inverse are used in evaluation to determine the stored value. Before the onset of a read operation, the word line is held low (grounded) and the two bit lines connected to the cell through transistors M5 and M6 are pre-charged high (to Vdd). Since the gates of M5 and M6 are held low, these access transistors are off and the cross-coupled latch is isolated from the bit lines. If a '0' is stored on the left

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storage node, the gates of the latch to the right are low. That means that transistor M3 (see figure.1) is initially turned off. In the same way M2 will also be off initially since its gate is held high. This results in a simplified model, shown in fig.2 for reading a stored '0'.

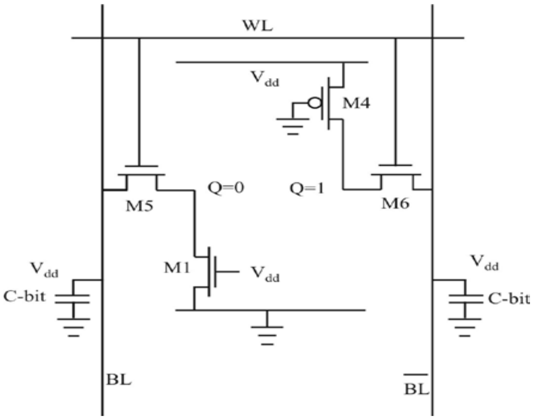

Figure 2. Six-transistor SRAM cell at the onset of read operation (reading '0').

The cell capacitance has here been represented only through the value held by each inverter (Q=0 and Q=1 respectively). The next phase of the read operation scheme is to pull the word line high and at the same time release the bit lines. This turns on the access transistors (M5 and M6) and connects the storage nodes to the bit lines. It is evident that the right storage node (the inverse node) has the same potential as BL and therefore no charge transfer will be take place on this side. The left storage node, on the other hand, is charged to '0' (low) while BL is pre-charged to VCC. Since transistor M5 now has been turned on, a current is going from C-bit to the storage node. This current discharges BL while charging the left storage node.

For a standard 6T SRAM cell, writing is done by lowering one of the bit lines to ground while asserting the word line. To write a '0' BL is lowered, while writing a '1' requires BL to be lowered. As in the previous example of a read, the cell has a '0' stored and for simplicity the schematic has been reduced in the same way as before. The main difference now is that the bit lines no longer are released. Instead they are held at Vdd and Gnd. If we look at the left side of the memory cell (M1-M5) it is virtually identical to the read operation (fig.3). Since both bit lines are now held at their respective value, the bit line capacitances have been omitted. During the discussion of read operation, it was concluded that transistor M1 had to be stronger than transistor M5 to prevent accidental writing. Now in the write case, this feature actually prevents a wanted write operation. Even when transistor M5 is turned on and current is flowing from BL to the storage node, the state of the node will not change.

As soon as the node is raised, transistor M1 will sink current to ground and the node is prevented from reaching even close to the switching point. So instead of writing a '1' to the node, we are forced to write a '0' to the

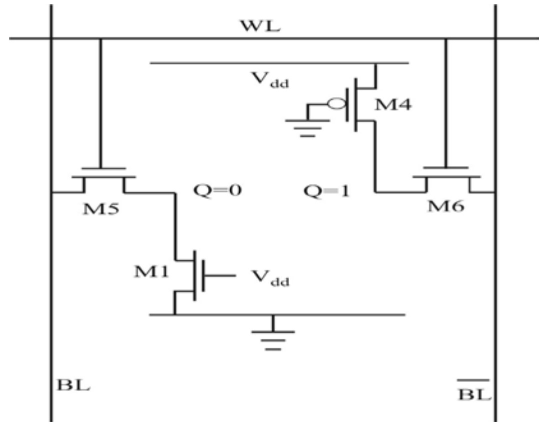

Figure 3. Six-transistor SRAM cell at the onset of write operation (writing '0','1').

inverse node. When the word line is raised M6 is turned on and current is drawn from the inverse storage node to BL. At the same time, M4 is turned on and as soon as the potential at the inverse storage node starts to decrease, current will flow from VCC to the node. In this case M6 has to be stronger than M4 for the inverse node to change its state. The transistor M4 is a PMOS transistor and inherently weaker than the NMOS transistor M6 (the mobility is lower in PMOS than in NMOS). Therefore, making both of them minimum size, according to the process design rules, will assure that M6 is stronger and that writing is possible. When the inverse node has been pulled low enough, the transistor M1 will no longer be open and the normal storage node will also flip, leaving the cell in a new stable state. The sizing for 6T SRAM cell can be used for comparisons

III. Simulation Results

A static RAM with six transistors, making a flip flop circuit with bistable states is widely used. The bistability of the SRAM cell can be observed using its eye property. In order to hold data, the static noise margin (SNM), defined by the size of the eye and should be kept large. The specification of SNM is such that are liable eye property is maintained despite the process fluctuations, variations in the operating conditions such as temperature and voltage, and bit-line noise. Since SNM becomes small with the reduction of the supply voltage, it becomes weaker against the threshold-voltage variation. In order to obtain high SNM, higher threshold voltage and high beta ratio are beneficial. By increasing the beta ratio, the slope becomes steeper and the eye becomes larger. This

Func. Block	Macroc ell	Inputs	Product Terms	Pins
FB1	16 / 18	18 / 36	44 / 90	5 / 9
FB2	14 / 18	27 / 36	21 / 90	6 / 9
FB3	15 / 18	32 / 36	71 / 90	5 / 8
FB4	16 / 18	31 / 36	52 / 90	7 / 8

Table1- Functional blocks of Static RAM

increase of beta ratio results in an area increase. Higher threshold voltage makes the eye larger, though it must be kept lower than half of Vdd. If Vth becomes much larger than half of Vdd, the eyes disappear and SRAM does not work properly.

Moreover, in the case of a memory array (for example, 512 cells connected together on a single bit line), the OFF-state current and the gate-leakage current of the transfer gate will appear from each bit in a bit line despite the word line being off. When the integral value of this OFF-state current and the gate-leakage current becomes comparable to the cell current, which is supposed to be turned on by the word line, the reading operation will fail. Therefore, both small leakage of the transfer gate and large cell current are required. A longer gate length for transfer transistor and a wide width for driver are stable but result in a reduced density. Using Xilinx ISE 10.1 release version, the implementation of memory write cycle is successfully performed. First of all source for process implementation is selected. It allows opening new source. On opening new source, VHDL module and file name is selected. Next step is to define the module, which can be defined by giving port name and direction (in/out/inout). Now project navigator creates a new Skelton source with a given specifications. After finishing, writing the program and saving it, implementation process allows synthesizing. During synthesize-XST, RTL schematic view of Signal 'clk16x' mapped onto global clock net GCK1. The complement of 'clk16x' mapped onto global clock net GCK3.Global output enables net(s) unused. There are 61 macrocells in high performance mode (MCHP).There are 0 macrocells in low power mode (MCLP). The following fig. 4 shows RTL schematic view of Static RAM.

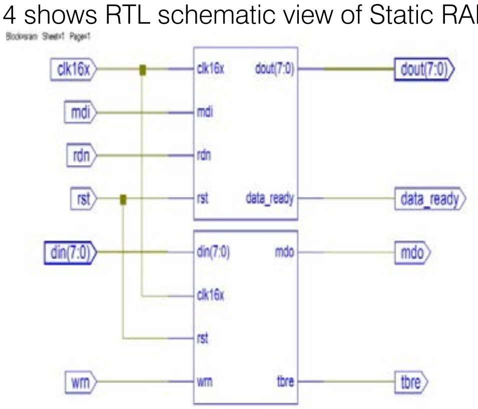

Figure 4. Internal architecture of Static RAM.

Filter report states about functional blocks and he detail of function blocks is illustrated in following table 1.

Non destructive read out characteristics of SRAM never require restoration of cell data, allowing the elimination of a sense amplifier on each data line. To obtain a fast read, the cell signal on the data line is made as small as possible, transmitted to the common U0 line through the column switch, and amplified by a sense amplifier. Since the cell signal is developed as the ratio voltage of data-line load impedance to cell transistors, a ratio current ZDC flows along the data line during word-line activation. Here, data-line charging current is negligibly small due to a very small AV, (= 0.1 V N 0.3 V), although it is prominent for write operation. Thus the current for read operation is expressed as

$$I_{DD} \cong [m i_{DC} \Delta t + C_{PT} V_{INT}] f + I_{DCP}.$$

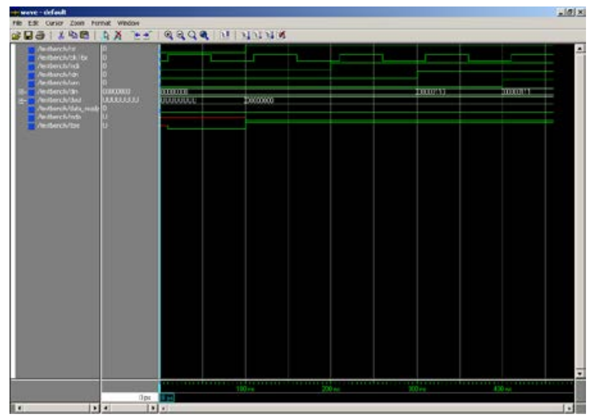

Figure 5. Simulation waveform of Static Ram.

Table 2. Signals and ports of Static RAM

Type	Name
Input Port	rst
Input Port	clk16x
Input Port	mdi
Input Port	rdn
Input Port	wrn
Input Port	din [7:0]
Output Port	dout [7:0]
Output Port	data_ready
Output Port	mdo

Due to larger width of pull down transistors in6T SRAM cell, finger type layout has been used for it.
Layout for different SRAM cell is shown in figure 6.

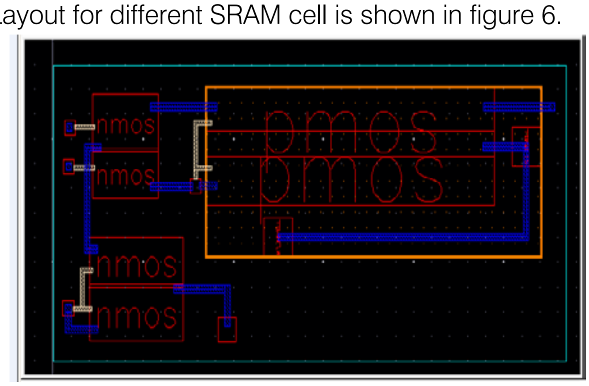

Figure 6. Layout of 6T SRAM cell.

The experimental evaluation includes analysis of power dissipation, delay and static noise margin. It is shown in following table 3.

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Table 3 Experimental evaluation of basic six transistocell

S.No.	Write zero power (μW)	Write one power (μW)	Write zero delay (ns)	Write one delay (ns)	Static noise margin (mV)
1.	232.2	44	0.75	0.84	360
2.	246.8	49	0.89	0. 92	387
3.	223.4	39	0.68	0.81	323
4.	219.7	37	0.61	0.76	319

IV. Conclusions & Remarks

An innovative 6T SRAM cell concept has been proposed and validated in 45nm MCFET technology. The simulation results have shown the great potential of the proposed approach for optimizing both the cell stability and the power consumption (higher than 25%) without any area penalty and for the same read access time. The concept is well adapted for all applications, low power and high performance. Thus, IREAD can be adjusted (weakened or reinforced) for the same cell size by increasing or reducing the number of stacked silicon films. The proposed approach can also be extended to nano-Wires technology or Si Bulk technologies with a selective dip of the STI to generate trigate structures on the edges of active area, where a greater width is needed.

The trend of SRAM technology is moving towards high-density, high-speed and low-power. Higher density and higher speed are achieved by scaling. Reduction of the gate oxide leakage current is essential to achieve high-speed keeping low standby current. Pattern formation processes, lithography and dry etching are the main concerns to miniaturization. Low power consumption is achieved by reduction of the power supply and invention of the circuit design. New technology, such as Cu interconnects and low 'K' dielectrics are introduced for high-speed operation. For lower cost and higher performance, the fabrication process is moving towards single-wafer processing in 300-mm wafer size. Process integration for the single-wafer process is the key to future technology. Failure analysis also requires innovation for future devices.

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Investigation into the Floor Diaphragms Flexibility in Reinforced Concrete Structures and Code Provision

By Morteza Moeini, Behzad Rafezy

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In this paper a review of the provisions of some modern seismic codes for the analytical modeling of the floor diaphragm action is made and a methodology using finite elements models, taking into consideration the in-plane flexibility, for monolithic floor is suggested. Using this method with comparative response-spectrum dynamic analyses, some reinforced concrete structures with different plan shapes like T-shape, L-shape, U-shape and rectangular according to 2800 (Iranian seismic code) are analyzed. Then, the efficiency of codes provisions is investigated.

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INVESTIGATION INTO THE FLOOR DIAPHRAGMS FLEXIBILITY IN REINFORCED CONCRETE STRUCTURES AND CODE PROVISION

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Abstract- All the seismic codes generally accept that in most cases the floor diaphragms may be modeled as fully rigid without in-plane deformability. Even though a rigid floor diaphragm is a good assumption for seismic analysis of the most buildings, several building configurations may exhibit significant flexibility in floor diaphragms. In these configurations, some codes like (EC8, NZS4203, GSC-2000) set certain qualitative criteria related to the shape of the diaphragm, while some others (2800, UBC-97, SEAOC-90, FEMA-273) set quantitative criteria relating the in-plane deformation of the diaphragm with the average drift of the associated storey.

In this paper a review of the provisions of some modern seismic codes for the analytical modeling of the floor diaphragm action is made and a methodology using finite elements models, taking into consideration the in-plane flexibility, for monolithic floor is suggested. Using this method with comparative response-spectrum dynamic analyses, some reinforced concrete structures with different plan shapes like T-shape, L-shape, U-shape and rectangular according to 2800 (Iranian seismic code) are analyzed. Then, the efficiency of codes provisions is investigated.

Keywords: rigid floor diaphragm, flexible floor diaphragms, average drift, in-plan deformation, floor diaphragm action, response-spectrum analysis.

I. Introduction

In the analysis of multistory buildings subjected to lateral loads, a common assumption is that the floor system undergoes no deformation in its own plan [1, 2]. Building structures are typically designed using the assumption that the floor systems serve as a rigid diaphragm between the vertical elements of the lateral load-resisting system. For the majority of buildings, floor diaphragms offer the most economical and rational method of resisting the lateral forces, since they are ordinarily included in the buildings to support the vertical workloads. It is thus, of the utmost importance, that they must be provided with sufficient in-plane stiffness and strength, together with efficient connections to the vertical structural elements. Muto (1974) used a beam with bending and shear deformation effects to simulate the behavior of flexible floors in buildings. Jain (1984) also used this beam including flexible and shear deformation effects to generate a solution to find the flexible-floor effect under the dynamic analysis. Saffarini and Qudaimat (1992) analyzed 37 reinforced concrete buildings to compare the difference between static rigid-floor and flexible-floor analyses. They found that the rigid-floor assumption is accurate for buildings without shear walls, but it can cause errors for building systems with shear walls. The quantitative investigation of the difference between the flexible-floor and rigid-floor analyses of buildings with shear walls was not found in their study and appears to be absent in the literature. Ju and Lin (1999) investigated the difference between rigid-floor and flexible-floors. They found that the rigid-floor assumption can cause errors for building system with shear walls. A quantitative investigation is made and an error formula is generated using the regression analysis of the rigid-floor and flexible-floor analyses from 520 rectangular, U-shaped, and T-shaped buildings. The effect of opening in slab was not found in their study and appears to be absent in the literature. Busu and Jain (2004) investigate the influence of floor diaphragm flexibility in asymmetric buildings. They investigate the effect of torsional code provisions in asymmetric buildings. They concluded that torsional effects may be quite significant in buildings with a flexible floor diaphragm (in semi-rigid structures specially). In such buildings, neither the floor diaphragm flexibility nor the torsional response can be ignored. Moreover, ignoring either accidental torsion or torsional amplification may cause significant differences in design forces. However, when the floor diaphragm is completely or significantly flexible (Tena-Colunga and Abrams 1996), each individual frame responds almost independently without any interference from the others and the torsional contribution may be significantly diminished.

In this paper a review of the provisions of some modern seismic codes for the analytical modeling of the floor diaphragm action is made and a methodology using finite elements models, taking into consideration the in-plane flexibility, for monolithic floor is suggested. Using this method with comparative response-spectrum dynamic analyses, some reinforced concrete structures with different plan shapes like T-shape, L-shape, U-shape and rectangular according to 2800 (Iranian seismic code) are analyzed. Then, the efficiency of codes provisions is investigated. This article has 3 sections, in first section the results of building

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analyses is investigated, in second section, codes provisions is investigated via the results of building analyzes and in third section, the quantitative criteria of codes provision is investigated via an error formula.

II. Code Provisions

In this section a review of the provisions of some modern seismic codes for the analytical modeling of the floor diaphragm action is made. All the seismic codes generally accept that in most cases the floor diaphragms may be modeled as fully rigid without in-plane deformability. Even though a rigid floor diaphragm is a good assumption for seismic analysis of the most buildings, several building configurations may exhibit significant flexibility in floor diaphragms. In these configurations, some codes like (EC8, NZS4203, GSC-2000) set certain qualitative criteria related to the shape of the diaphragm, while some others (2800, UBC-97, SEAOC-90, FEMA-273) set quantitative criteria relating the in-plane deformation of the diaphragm with the average drift of the associated storey.

III. Uniform Building Code [UBC, 1994]

Diaphragms shall be considered flexible for the purposes of distribution of storey shear and torsional moment when the maximum lateral deformation of the diaphragm ($\Delta_{flexible}$) is more than twice the average storey drift of the associated storey (Δ_{story}) (Fig. 1). The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection which permits the attached element to maintain its structural integrity under the individual loading and continue to support the permissible loads [12]. Floor and roof diaphragms shall be designed to resist the forces determined in accordance with given formulas [12].

In the other word diaphragm is rigid when:

$$\beta = \frac{\Delta_{flexible}}{\Delta_{Story}} < 2 \quad (1)$$

And it is flexible when:

$$\beta = \frac{\Delta_{flexible}}{\Delta_{Story}} \geq 2 \quad (2)$$

IV. Structural Engineers Association of California [SEAOC, 1990]

Diaphragms shall be considered flexible when the maximum lateral deformation of the diaphragm is more than twice the average drift of the associated storey ($\beta \geq 2$) [9]. The term “flexible” implies that the diaphragm may be modelled as a simple beam (horizontal girder) between vertical resisting elements, whose cross section is composed of connected web and flange elements. The web (shear resisting element) is provided by the floor or roof deck, while chord or boundary members serve as flanges to resist the axial tension or compression resulting from flexural action [9]. This girder analogy should not be regarded as complete and should only be considered as an approximation, usually having the special properties of deep beams (shear deformations etc.) [9].

In most cases the diaphragm may be modelled as “fully rigid” without in-plane deformability. However there are structural configurations such as vertical resisting elements having large differences in stiffness or offsets between stories, and diaphragms with irregular shapes and/or openings, where the Engineer should investigate the effects of diaphragm deformability. The use of the most critical results obtained from the “fully rigid” and the “flexible” models would be acceptable [9].

IRAN SESMIC CODE-THIRD EDITION (2800)

Floor diaphragms shall be classified as either “flexible” or “rigid”. “Flexible” when the maximum lateral deformation of the diaphragm along its length is more than half the average inter-storey drift of the storey immediately below, “rigid” when this lateral deformation of the diaphragm is less than half the average inter-storey drift of the associated storey. The inter-storey drift and diaphragm deformations shall be estimated using the seismic lateral forces. The term “flexible” implies that the diaphragm may be modelled as a simple beam (horizontal girder) between vertical resisting elements, whose cross section is composed of connected web and flange elements. The web (shear resisting element) is provided by the floor or roof deck, while chord or boundary members serve as flanges to resist the axial tension or compression resulting from flexural action. This girder analogy should not be regarded as complete and should only be considered as an approximation, usually having the special properties of deep beams (shear deformations etc.) [15].

In the other word diaphragm is rigid when:

$$\lambda = \frac{\Delta_{diaph}}{\Delta_{Story}} < 0.5 \quad (3)$$

And it is flexible when:

$$\lambda = \frac{\Delta_{diaph}}{\Delta_{Story}} \geq 0.5 \quad (4)$$

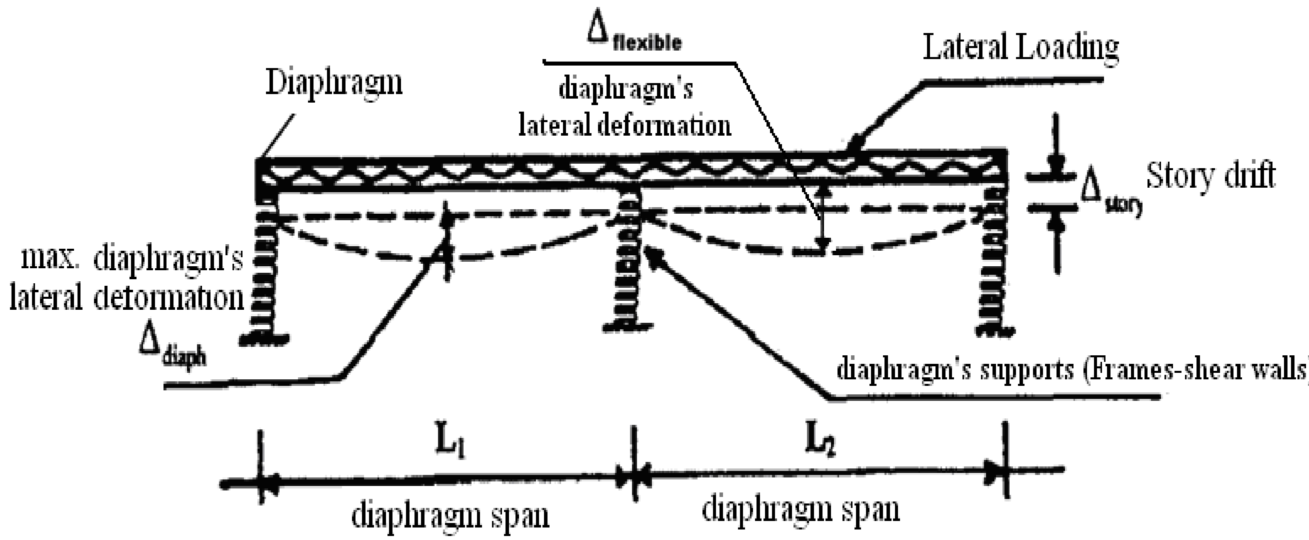

FIG. 1. Simulation of diaphragm with a simple deep beam [15]

V. Federal Emergency Management Agency [FEMA 1997]

Floor diaphragms shall be classified as either "flexible", "stiff", or "rigid". "Flexible" when the maximum lateral deformation of the diaphragm along its length is more than twice the average inter-storey drift of the storey immediately below ($\lambda \geq 2$), "rigid" when this lateral deformation of the diaphragm is less than half the average inter-storey drift of the associated storey ($\lambda < 0.5$) and "stiff" when the diaphragm it is neither flexible nor rigid ($0.5 \leq \lambda < 2$). The inter-storey drift and diaphragm deformations shall be estimated using the seismic lateral forces. The in-plane deflection of the floor diaphragm shall be calculated for an in-plane distribution of lateral force consistent with the distribution of mass, as well as all in-plane lateral forces associated with offsets in the vertical seismic framing at that floor [13].

Mathematical models of buildings with stiff or flexible diaphragms should be developed considering the effects of diaphragm flexibility. Floor diaphragms shall be designed to resist the effects of the inertia forces developed at the level under consideration and the horizontal forces resulting from offsets or changing in stiffness of the vertical seismic framing elements above and below the diaphragm. For concrete diaphragms, the analytical model can typically be taken as a continuous or simple span horizontal elastic beam that is supported by elements of varying stiffness. The beam may be rigid or semi-rigid. When the length-to-width ratio of the diaphragm exceeds 2.0, the effects of diaphragm deflection shall be considered when assigning lateral forces to the resisting vertical elements [13].

Eurocode 8 [EC8, 1994]

When the floor diaphragms are sufficiently rigid in their plane, the masses and the moments of inertia of each floor may be lumped at its centre of gravity. The seismic design shall cover the verification of reinforced concrete (RC) diaphragms in the following cases of Ductility Class "H" structures [11]:

- Irregular geometries or divided shapes in plan, recesses, re-entrances
- Irregular and large openings in the slabs
- Irregular distribution of masses and or stiffness
- Basements with walls located only in part of their perimeter, or only in part of the ground floor area.

In these cases, action effects in RC diaphragms may be estimated by modeling them as deep beams on yielding supports or plane trusses. In steel buildings, concrete floor diaphragms may be considered as rigid for the dynamic analysis without further verification, if the openings in them do not significantly affect the overall in-plane rigidity of the floor and they are constructed according to Chap. 2 [11].

When the floor diaphragms of the building may be taken as being rigid in their planes, the masses and the moments of inertia of each floor may be lumped at the centre of gravity [11].

- The diaphragm is taken as being rigid, if, when it is modelled with its actual in-plane flexibility, its horizontal displacements nowhere exceed those resulting from the rigid diaphragm assumption by more than 10% of the corresponding absolute horizontal displacements in the seismic design situation [11].

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VI. Greek Seismic Code [GSC, 2000]

In buildings subjected to horizontal seismic actions, if the in-plane stiffness of the diaphragms is assured to be large ("rigid floors"), then the mass properties of each diaphragm may be lumped at its centre of mass (reducing the independent in-plane degrees of freedom to three per floor), else additional degrees of freedom must be considered [14].

The shape of the floors in plan must guarantee the "rigid floor" diaphragm action in point of stiffness and strength. For this reason, long shapes in plan (length to width ratio ≥ 4) must be avoided, as well as plan shapes composed of long parts (L, Π, etc.) or with large re-entrances. When this is not possible, the effects of the in-plane floor flexibility to the distribution of the lateral forces at the vertical resisting elements must be taken into consideration and the strength capacity at the weak areas of the diaphragm must be checked [14].

VII. Standards Association of New Zealand [NZS 4203, 1992]

When there are abrupt discontinuities, major variations in in-plane stiffness or major re-entrant corners in diaphragms, the assumption of a rigid diaphragm may not be valid. In some cases, investigation of the effects may be require the stiffness of the diaphragm to be modelled in the analysis to ensure that a realistic distribution of lateral force has been obtained [10].

VIII. Structural Modelling and Analysis Framework

The total number of degrees of freedom is equal to three times the total number of slaved nodes and master nodes in the mesh for a three-dimensional (3D) building analysis. For building analyses under the flexible-floor assumption, each node contains six degrees of freedom — three translations and three rotations. Thus, the number of degrees of freedom for the flexible-floor mesh is about twice as large as that for the rigid-floor mesh.

For the equivalent static lateral force method, the horizontal forces are often applied to the master nodes of a rigid-floor analysis. However, it is difficult to add these horizontal forces to the nodes of a building with the flexible-floor assumption. For example, adding these horizontal forces only to the node at the mass center of each floor will cause stress concentration near the mass center. Thus, to compare the results of the rigid-and flexible-floor analyses, dynamic analysis is probably a better choice since the earthquake loading can be applied to the building base without any differentiation between the rigid and flexible-floor analyses. Forced dynamic analyses include time-history and response-spectrum analyses. For time-history analysis, it is not easy to compare the complex analysis results between the rigid- and flexible-floor analyses. For example, the two results may differ due to a significant time shift, so comparing them at a certain time will cause error. The response-spectrum analysis does not have this problem, since only the maximum responses are calculated in this method. Thus this method with the response spectrum of the 2800 code (Fig. 2) is used to perform the two types of building analyses. In the dynamic analysis, the mode superposition method is used, and the first 30 modes are calculated to perform the response to perform the response-spectrum analysis. The effective masses of the x-translation, y-translation and z-rotation for these 30 modes are always larger than 95% of their total masses in our building analyses.

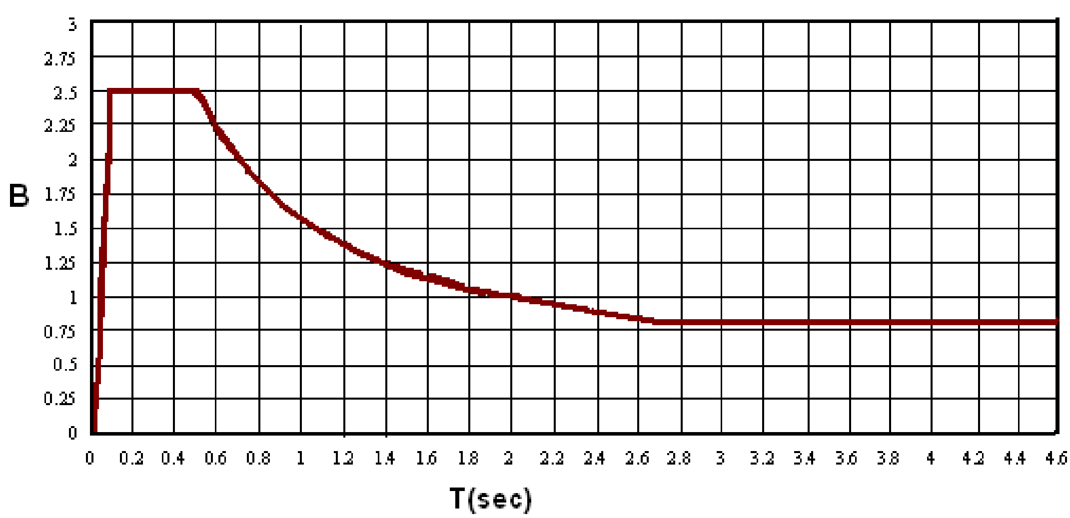

FIG.2- Response Spectrum of 2800 Code [15]

For the analytical modeling and dynamic analyses of the structures considered, the computer program SAP2000 was used. The floor diaphragms and shear walls are modeled with shell elements.

IX. Characteristics of Buildings

For the investigation of codes provisions, some reinforcement concrete buildings with T-shaped, L-shaped, U-shaped and rectangular plan shape are considered. Fig 3 shows the plans shape and position of shear walls. These buildings are analyzed with shear wall and without shear walls. 3-story T-shaped building consists of two long rectangular interconnected parts, with aspects ratio ≈ 1:4 and 1:5. 4-story L-shaped building consists of two long rectangular interconnected parts, with aspects ratio ≈ 1:4.5 for each of them. 6-story U-shaped building consists of three long rectangular interconnected parts, with aspects ratio ≈ 1:3.75 and 1:5.2. The floor plan in rectangular building has a rectangular shape with aspect ratio 1:4.

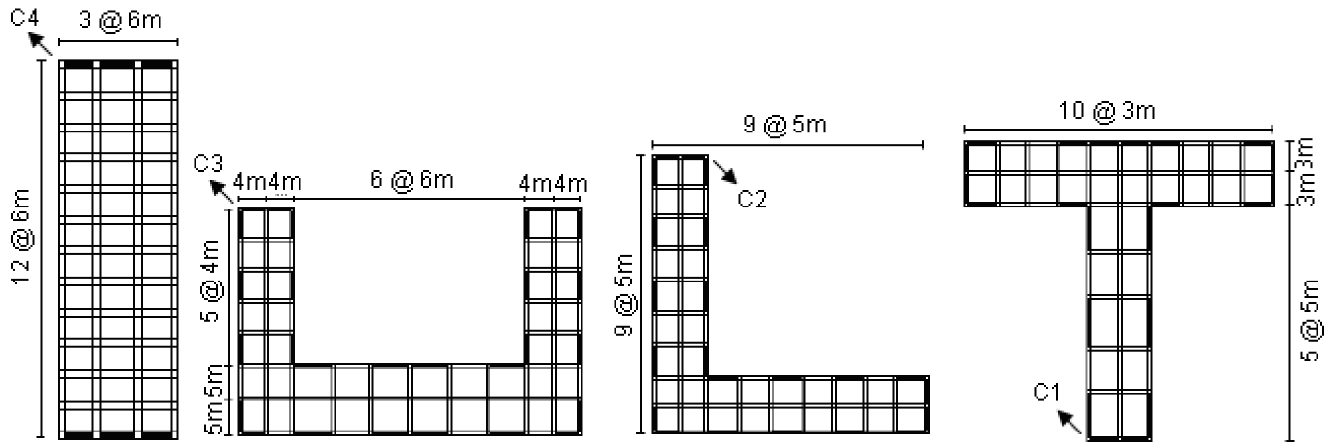

FIG. 3 Plan shape and position of shear walls

Member sizes and other properties of the structures are shown in the table 1. In T-shaped building, the beams with 3m length have 30X70cm section, and beams with 5m length, have 50X70cm section. In U-shaped building, the beams with 3m length have 30X80cm section, beams with 4m length have 40X80cm section, and beams with 5m length have 50X80cm section.

Table1- Member Sizes and other properties of buildings

Shape of buildings	Beam section (cm)	Column section (cm)	Slab thickness (cm)	Shear wall thickness (cm)	Number of stories	Story height (m)
T-shape	30X70 50X70	50X50	12	12	3	4
L-shape	40X80	50X50	12	15	4	4
	30X80					
U-shape	40X80 50X80	80X80	15	30	6	4
Rectangular	50X80	80X80	15	15	5	4

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X. First Section, Results of Analyses

The buildings with and without shear walls, and with rigid and flexible diaphragm assumption are analyzed. From the results obtained of a number of response-spectrum analyses, the rigid floor model was found to be accurate enough for buildings without shear walls. However, the difference between the rigid-floor and flexible-floor analyses can be large for the buildings with shear walls. In each building a diagram indicates the difference between two types of analyses. In mentiond diagrams, the axial force (in selected column in fig 3) is used as X-direction and story level is used as Y-direction.

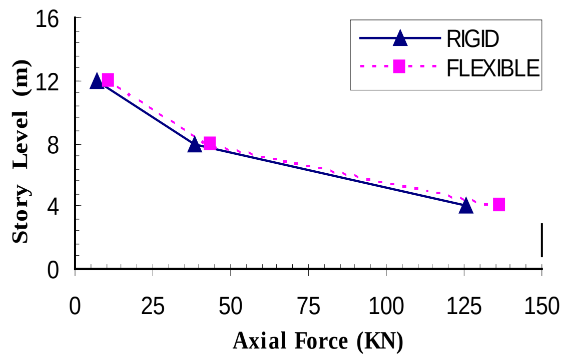

FIG. 4. Axial forces of C1 in T-shaped building without shear walls under Y-Y direction earthquake

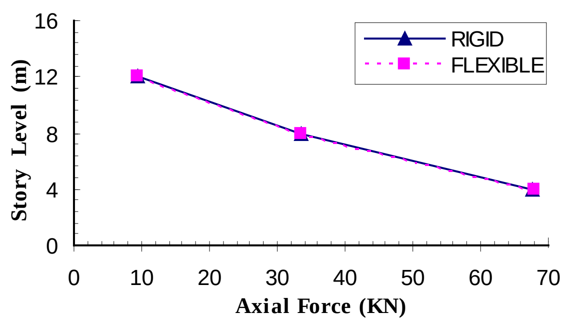

FIG 5- Axial forces of C1 in T-shaped building with shear walls under Y-Y direction earthquake

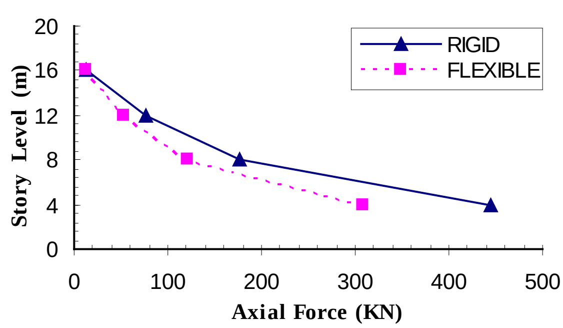

FIG 6-Axial forces of C2 in L-shaped building without shear walls under Y-Y direction earthquake

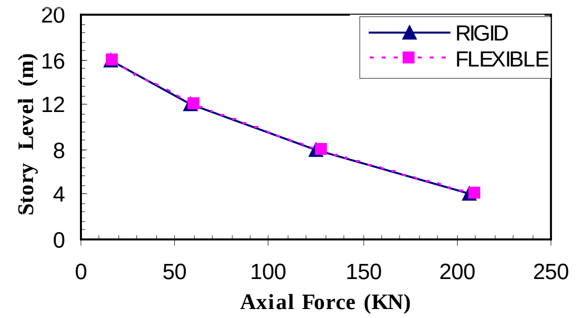

FIG. 7. Axial forces of C2 in L-shaped building with shear walls under Y-Y direction earthquake

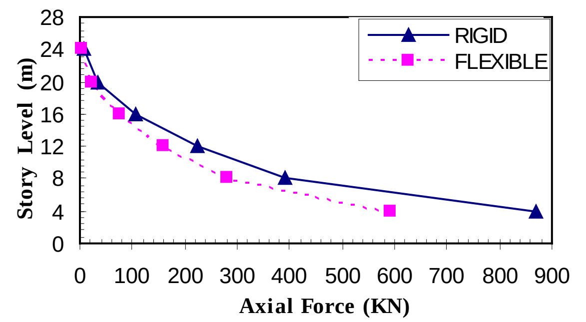

FIG. 7. Axial forces of C3 in U-shaped building without shear walls under Y-Y direction earthquake

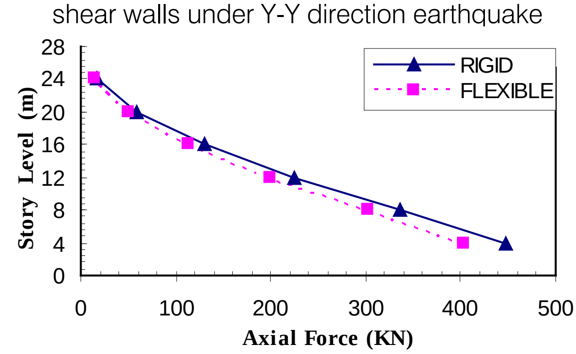

FIG. 8. Axial forces of C3 in U-shaped building with shear walls under Y-Y direction earthquake

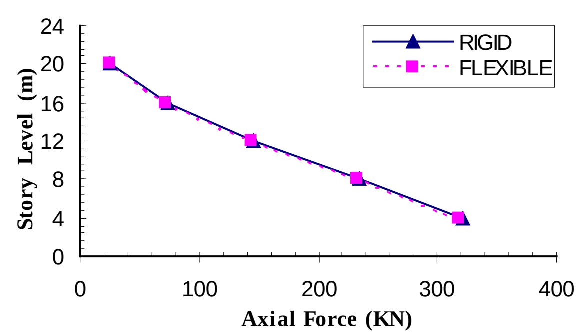

FIG.9- Axial forces of C4 in Rectangular building without shear walls under X-X direction earthquake

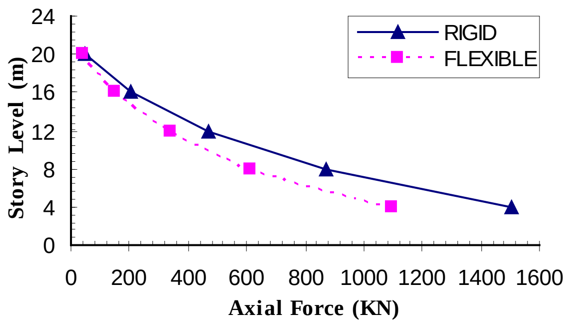

FIG10- Axial forces of C4 in Rectangular building with shear walls under X-X direction earthquake

Above figures illustrate the analysis differences. These figures indicate that the maximum difference between the rigid floor and flexible floor building analyses for T-shaped building with shear walls is approximately 32%. This difference, for T-shaped building without shear walls is less than 1%, for L-shaped building with and without shear walls respectively is about 46% and 4%, for U-shaped building with and without shear walls respectively is about 75 and 25, for rectangular building with and without shear walls respectively is about 42% and 1%. It is concluded in the most building with shear walls, difference between two types of analysis is low. Since in the buildings without shear walls, the in-plan floor deformation is more than lateral deformation, the rigid floor assumption is accurate for these buildings.

XI. Second Section, Investigation of Codes Provisions via the Results of Analyses

In this section codes provisions are investigated by use the results of building analyses. In order to set the conditions under which the in-plane deformability must be taken into consideration, some codes (EC8, NZS4203, GSC) set certain qualitative criteria related to the shape of the diaphragm, while some others (UBC, SEAOC, FEMA) set quantitative criteria relating the in-plane deformation of the diaphragm with the average drift of the associated storey, as mentioned above.

1. *UBC-97 and SEAOC-90 quantitative criteria*

The provisions of these codes for about the diaphragm, is similar and diaphragms shall be considered flexible when the maximum lateral deformation of the diaphragm is more than twice the average drift of the associated storey ($\beta \geq 2$) and diaphragms shall be considered flexible when ($\beta < 2$). The values of β are shown in tables 2 and in accordance with that in buildings with shear walls, only the rectangular building is flexible and other T-shaped, L-shaped and U-shaped buildings are rigid. All of the buildings without shear walls are rigid.

TABLE 2. The values of β

Building type		Max of β	Associated story
Buildings with shear walls	T-shaped	1.22	Rigid
	L-shaped	1.68	Rigid
	U-shaped	1.51	Rigid
	Rectangular	2.00	Flexible
Buildings without shear walls	T-shaped	1.02	Rigid
	L-shaped	1.02	Rigid
	U-shaped	1.03	Rigid
	Rectangular	1.02	Rigid

2. *2800 quantitative criteria*

Diaphragms shall be considered flexible when the maximum lateral deformation of the diaphragm along its length is more than half the average inter-storey drift of the storey immediately below ($\lambda > 0.5$), and diaphragms shall be considered flexible when ($\lambda < 0.5$). The values of λ are shown in tables 3 and in accordance with that in buildings with shear walls, only the T-shaped building is rigid and other L-shaped, U-shaped and rectangular buildings are flexible. All of the buildings without shear walls are rigid.

TABLE 3. The values of λ

Building type		Max of λ	Associated story
Buildings with shear walls	T-shaped	*0.22*	*Rigid*
	L-shaped	*0.68*	*Flexible*
	U-shaped	*0.51*	*Flexible*
	Rectangular	*1.00*	*Flexible*
Buildings without shear walls	T-shaped	*0.019*	*Rigid*
	L-shaped	*0.018*	*Rigid*
	U-shaped	*0.03*	*Rigid*
	Rectangular	*0.015*	*Rigid*

3. *FEMA-273 quantitative criteria*

Floor diaphragms shall be classified as either “flexible”, “stiff”, or “rigid”. “Flexible” when the maximum lateral deformation of the diaphragm along its length is more than twice the average inter-storey drift of the storey immediately below ($\lambda \geq 2$), “rigid” when this lateral deformation of the diaphragm is less than half the average inter-storey drift of the associated storey (

$\lambda < 0.5$) and "stiff" when the diaphragm it is neither flexible nor rigid ($0.5 \le \lambda < 2$). In accordance with table 3 in buildings with shear walls, the T-shaped building is rigid, the L-shaped, U-shaped and rectangular buildings are semi-rigid (stiff). All of the buildings without shear walls are rigid.

4. EUROCODE 8 [EC8] qualitative criteria

Since all of the buildings in fig 3 have irregular geometries or divided shapes in plan, recesses, re-entrances, are classified in Class "H" structures. The diaphragm is considerd rigid, if, when it is modelled with its actual in-plane flexibility, its horizontal displacements nowhere exceed those resulting from the rigid diaphragm assumption by more than 10% of the corresponding absolute horizontal displacements in the seismic design situation, and accordance with this observation, all of the buildings with shear walls are flexible and all of the buildings without shear walls are rigid.

5. Greek Seismic Code [GSC, 2000] qualitative criteria

The shape of the floors in plan must guarantee the "rigid floor" diaphragm action in point of stiffness and strength. For this reason, long shapes in plan (length to width ratio ≥ 4) must be avoided, as well as plan shapes composed of long parts (L, Π, etc.) or with large re-entrances. When this is not possible, the effects of the in-plane floor flexibility to the distribution of the lateral forces at the vertical resisting elements must be taken into consideration. Since all of the structures have long rectangular interconnected parts, with aspects ratio ≥ 4, then all of the buildings with and without shear walls are flexible.

6. Standards Association of New Zealand [NZS 4203, 1992] qualitative criteria

When there are abrupt discontinuities, major variations in in-plane stiffness or major re-entrant corners in diaphragms, the assumption of a rigid diaphragm may not be valid. In some cases, investigation of the effects may be requiring the stiffness of the diaphragm to be modelled in the analysis to ensure that a realistic distribution of lateral force has been obtained. The qualitative criteria of this code is rather ambiguous and non-objective, because the criteria has not determinate the limit of itself. So, if the large rectangular interconnected parts suppose that are abrupt discontinuities, then all of the buildings with and without shear walls are flexible.

Table 4 indicates the classification of buildings diaphragms behavior

Building type		2800	SEAOC-90	UBC-97	FEMA-273	EC8	NZS4203	GSC-2000
Buildings with shear walls	T-shaped	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible	Flexible
	L-shaped	Flexible	Rigid	Rigid	Stiff	Flexible	Flexible	Flexible
	U-shaped	Flexible	Rigid	Rigid	Stiff	Flexible	Flexible	Flexible
	Rectangular	Flexible	Flexible	Flexible	Flexible	Flexible	Flexible	Flexible
Buildings without shear walls	T-shaped	Rigid	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible
	L-shaped	Rigid	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible
	U-shaped	Rigid	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible
	Rectangular	Rigid	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible

XII. Third Section, Investigation of the Quantitative Criteria via the Error Formula

In this section the quantitative criteria in UBC-97, SEAOC-90, 2800 and FEMA-273 via an error formula that has presented in Ju and Lin (1999) study (equation (6)). Codes quantitative criteria only differ in the limit of rigidity. The aim of this section is to answer two following questions:

1- Has the limit of quantitative criteria in the mentioned codes enough accuracy?
2- If the first question's answer is negative, what is the accurate limit?

In accordance with Ju and Lin (1999) study as mentioned, they found that the rigid-floor assumption can cause errors for building system with shear walls. A quantitative investigation is made and an error formula is presented by them (6):

$$R = \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{flexible}} \quad (5)$$

$$Error\% = 81.53R + 3.8 \quad (6)$$

They concluded that if R<0.2, then the rigid floor assumption is accurate and if R>0.4, then the flexible-floor analysis should be used to replace the rigid-floor analysis. If 0.2<R<0.4 then the structures behavior is semi-rigid.

Each code has the special criteria that are mentioned in the above sections, some use Δ_{diaph} (2800 and FEMA-273) and some use $\Delta_{flexible}$ (UBC-97 and SEAOC-90) as shown in fig. 1. In this section in first the criteria become uniform and then its efficiency is tested with (6).

UBC-97 and SEAOC-90

Diaphragm is rigid when: $\frac{\Delta_{flexible}}{\Delta_{Story}} < 2$

Diaphragm is flexible when: $\frac{\Delta_{flexible}}{\Delta_{Story}} \geq 2$

2800

Diaphragm is rigid when: $\frac{\Delta_{diaph}}{\Delta_{Story}} < 0.5 \Rightarrow \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 < 0.5 \Rightarrow \frac{\Delta_{flexible}}{\Delta_{rigid}} < 1.5$

Diaphragm is flexible when: $\frac{\Delta_{diaph}}{\Delta_{Story}} > 0.5 \Rightarrow \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 > 0.5 \Rightarrow \frac{\Delta_{flexible}}{\Delta_{rigid}} > 1.5$

FEMA-273

Diaphragm is rigid when: $\frac{\Delta_{diaph}}{\Delta_{Story}} < 0.5 \Rightarrow \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 < 0.5 \Rightarrow \frac{\Delta_{flexible}}{\Delta_{rigid}} < 1.5$

Diaphragm is flexible when: $\frac{\Delta_{diaph}}{\Delta_{Story}} > 2 \Rightarrow \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 > 2 \Rightarrow \frac{\Delta_{flexible}}{\Delta_{rigid}} > 3$

Diaphragm is stiff when: $0.5 < \frac{\Delta_{diaph}}{\Delta_{Story}} < 2 \Rightarrow 0.5 < \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 < 2 \Rightarrow 1.5 < \frac{\Delta_{flexible}}{\Delta_{rigid}} < 3$

1. Comparison of the quantitative criteria

By comparison of the quantitative criteria in UBC-97, SEAOC-90, 2800 and FEMA-273, it is concluded that the criteria in 2800 and FEMA-273 is more conservative than UBC-97 and SEAOC-90. After the making criteria uniform, it is concluded the quantitative criteria for being rigid:

In FEMA-273 and 2800 is ⟶ $\frac{\Delta_{flexible}}{\Delta_{rigid}} < 1.5$

In UBC-97 and SEAOC-90 is ⟶ $\frac{\Delta_{flexible}}{\Delta_{rigid}} < 2$

2. Investigation of quantitative criteria accuracy

In this section we are going to answer the first mentioned question, R is obtained from (5), in accordance with 2800 and FEMA-273 codes the value of R is:

$$R = \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{flexible}} = \frac{\Delta_{flexible}/\Delta_{rigid} - 1}{\Delta_{flexible}/\Delta_{rigid}} = \frac{1.5-1}{1.5} = \frac{1}{3} = 0.33$$

And, in accordance with Ju and Lin (1999) study, in buildings with continuous symmetric shear walls, when R<0.2, the behavior of diaphragm is rigid, but in according to the 2800 and FEMA-273 quantitative criteria when R<0.33, the behavior of diaphragm is rigid. Thus, the quantitative criteria in building codes have not enough accuracy and they need to reform.

XIII. Reformation of Quantitative Critrria

In this section we are going to answer the second mentioned question and present an appropriate limit. If the limit of quantitative criteria for being rigid in more conservative codes (2800 and FEMA-273) is decreased to half of the former limit and then calculated the value of R, it is concluded that this suggestive limit is appropriate, because:

$$\frac{\Delta_{diaph}}{\Delta_{Story}} < 0.25 \Rightarrow \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{rigid}} = \frac{\Delta_{flexible}}{\Delta_{rigid}} - 1 < 0.25 \Rightarrow \frac{\Delta_{flexible}}{\Delta_{rigid}} < 1.25 \Rightarrow$$

$$\Rightarrow R = \frac{\Delta_{flexible} - \Delta_{rigid}}{\Delta_{flexible}} = \frac{\Delta_{flexible} / \Delta_{rigid} - 1}{\Delta_{flexible} / \Delta_{rigid}} = \frac{1.25 - 1}{1.25} = \frac{1}{5} = 0.2$$

Thus, if $\frac{\Delta_{flexible}}{\Delta_{rigid}} < 1.25$, the behavior of diaphragm in according to the codes and error formula is fully rigid and so the rigid-floor analysis is sufficiently accurate.

It should be say that in according to the study of the Busu and Jain (2004), the torsional effects may be quite significant in buildings with a flexible-floor diaphragm (in semi-rigid structures specially). Specifying of the limit for the classification of buildings to the flexible and semi-rigid diaphragm is difficult and requires to another study, thus in this study buildings are classified in rigid-floor and non-rigid-floor (include flexible and semi-rigid floor) diaphragm.

1. Reformation of UBC-97 and SEAOC-90 quantitative criteria

Diaphragms shall be considered flexible for the purposes of distribution of storey shear and torsional moment when the maximum lateral deformation of the diaphragm is more than 1.25 times the average storey drift of the associated storey. In the other word:

- Diaphragm is rigid when: $\frac{\Delta_{flexible}}{\Delta_{Story}} < 1.25$
- Diaphragm is flexible (non-rigid) when:

$$\frac{\Delta_{flexible}}{\Delta_{Story}} \geq 1.25$$

2. Reformation of 2800 and FEMA-273 quantitative criteria

Floor diaphragms shall be classified as "Flexible" when the maximum lateral deformation of the diaphragm along its length is more than quarter the average inter-storey drift of the storey immediately below, "rigid" when this lateral deformation of the diaphragm is less than quarter the average inter-storey drift of the associated storey. In the other word:

- Diaphragm is rigid when:

$$\frac{\Delta_{flexible}}{\Delta_{Story}} < 1.25 \quad \text{or} \quad \frac{\Delta_{diaph}}{\Delta_{story}} < 0.5$$

- Diaphragm is flexible (non- rigid) when:

$$\frac{\Delta_{flexible}}{\Delta_{Story}} \geq 1.25 \quad \text{or} \quad \frac{\Delta_{diaph}}{\Delta_{story}} \geq 0.5$$

XIV. Summary and Conclusions

1. All the codes generally accept that in most cases the floor diaphragms may be modelled as fully rigid without in-plane deformability. Furthermore, in order to set the conditions under which the in-plane deformability must be taken into consideration, some codes (EC8, NZS4203, GSC) set certain qualitative criteria related to the shape of the diaphragm, while some others (UBC-97, SEAOC-90, FEMA-273, 2800) set quantitative criteria relating the in-plane deformation of the diaphragm with the average drift of the associated storey.
2. The quantitative and qualitative criteria must be use with together.The quantitative criteria for classification of a floor diaphragm as "flexible", "stiff" or "rigid" (UBC-97, SEAOC-90, FEMA-273, 2800) are rather ambiguous and non-objective, because the determination of the in-plane deformations of the diaphragm depends on the forces acting on it, while these forces depend on the deformations to be determined.
3. The proposed deep-beam (EC8, SEAOC-90, FEMA-273, 2800) or plane-truss (EC8) models for the diaphragms generally contain many approximations and limitations regarding the shape, connectivity and stiffness properties of the floor diaphragms to be modelled, thus is recommended that it is better the diaphragm is analyzed in a 3D finit elements model.
4. The quantitative criteria in building codes have not enough accuracy and they need to reform.
5. The shape of the floors in plan must guarantee the "rigid floor" diaphragm action in point of stiffness and strength. For this reason, long shapes in plan (length to width ratio ≥ 3) must be avoided, as well as plan shapes composed of long parts (L, Π, etc.) or with large re-entrances, especially when the opening area is large than 50%. When this is not possible, the effects of the in-plane floor flexibility to the distribution of the lateral forces at the vertical resisting elements must be taken into consideration and the strength capacity at the weak areas of the diaphragm must be checked.

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Computer Simulation of a Gas Turbine Performance

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Abstract- The current research is aimed at carrying out an exergy analysis of a 33-MW gas turbine power plant that operates on the Brayton cycle. Quantitative exergy analysis for each component and for the whole system was done. Based on the exergy balance models developed, a computer program is written which is used to investigate the performance of the power plant under varying ambient and turbine inlet temperature conditions. The result obtained shows that the largest amount of exergy destruction occurs in the combustion chamber and the least in the gas turbine. The simulation reveals remarkable dependency of the exergy flow rate of the power output, exergy efficiency, exergy destruction, heat-to-power ratio and the specific fuel consumption on the change in the ambient temperature and turbine inlet temperature of the plant.

Keywords: *Exergy analysis, efficiency, gas turbine plant, irreversibility, computer program.*

Classification: *GJRE-A Classification (FOR): 091307, 091305*

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Strictly as per the compliance and regulations of:

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I. Introduction

The growth in electricity demand being experienced in Nigeria has resulted in the need to build power plants that generate maximum power output at ambient temperature. Due to their installation time, low installation cost and availability of natural gas in the country, many states of the country are currently building gas turbine power plants to meet this demand. However, one disadvantage that penalizes the gas turbine power rating is the adverse effect of the ambient temperature on the gas turbine power output and efficiency. In order to utilize the high economic and energy saving potential of a gas turbine power plant in their simple and combined cycles, it is important to identify their optimal design parameters and determine the impact of the deviation of these parameters from the standard conditions, on the overall performance of the plant. Gas turbines designed to operate at maximum efficiency at standard ambient temperatures and relative humidity may tend to reduce in performance due to adaptation problems resulting from variation in weather conditions as they are installed at different locations. Numerous methods of analysis of gas turbine systems have been proposed amongst which is the exergy method. The exergy method is a performance analysis of a thermal system based on the second law of thermodynamics which extends beyond the limits of energy-based analysis since exergy is generally not conserved as energy but is destroyed in the system. The exergy method assists the engineer in identifying the source and magnitude of performance loss in a thermal system by measuring the irreversibilities that occur in different devices and sections of the system. Significant works in the field of simple and cogeneration cycle gas turbine power plants have been recorded. Ogaji (1997) utilized first law to develop a computer simulation model for investigating the performance of various gas turbine cycles. Pankaj (2003) verified the impact of high ambient air temperature on the performance of various gas turbine models utilizing performance data obtained for each model as a basis for comparison and proposed the Earth Tube Heat Exchanger (ETHE) technology as the most effective and economical inlet air cooling method. Somkiat and Pichai (2004) performed an exergy evaluation of a combined steam and gas turbine plant to quantify exhaust loss and its effect on the environment. Mohamad and Mofid (2005) performed an exergy analysis of a regenerative gas turbine cycle to identify sources of performance loss in the plant. Naser (2005) compared various modified Brayton cycles with a regenerative, two-isothermal heat addition Brayton cycle using second law analysis. Kamal and Zuhair (2006) investigated the technical and economical feasibility of using turbine inlet air cooling and its effect on the performance of gas turbines in Khartoum which is a high ambient temperature and dusty area and proposed wetted media evaporative cooling to be the most economically feasible option for improving the performance of gas turbine plants in the area. Tamer (2006) determined the optimum design parameters of a Brayton- Heat Recovery Steam Generator (HRSG) cycle at maximum exergy and their effects on the exergetic efficiency. Sanjay et al (2009) utilized exergy analysis principles and a computer code to simulate the performance of a Brayton – diesel cycle. Ashok et al (2010) combined the first and second law analysis to develop a design methodology for parametric study and thermodynamic performance evaluation of a closed Brayton cycle with Heat Recovery Steam Generator (HRSG).

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In this paper, an exergy analysis was performed for a 33-MW gas turbine plant, which is an existing plant located in Port Harcourt, Nigeria. Mass and energy conservation laws were applied to each component and quantitative exergy balance of each component and the overall plant was also delivered. Based on the model equations developed, a computer program is written which serves as an efficient tool for quantifying the exergy flow rate at each state point in the cycle, evaluating the efficiencies and irreversibilities in each component and for the overall plant, and simulating the performance of the plant and its components when the ambient and turbine inlet temperatures are varied.

II. Problem Formulation and Solution Method

The schematic of a GE-MS6001, 33-MW single shaft gas turbine system which operates on Brayton cycle is given in Figure 1 and shows the main work and exergy flows and the state points which were accounted for in this analysis. The plant consists of an axial flow air-compressor (AC), a combustion chamber (CC), and a gas turbine (GT). Figure 2 is the T-s diagram showing the losses due to inefficiencies of the components of the actual open cycle gas turbine plant.

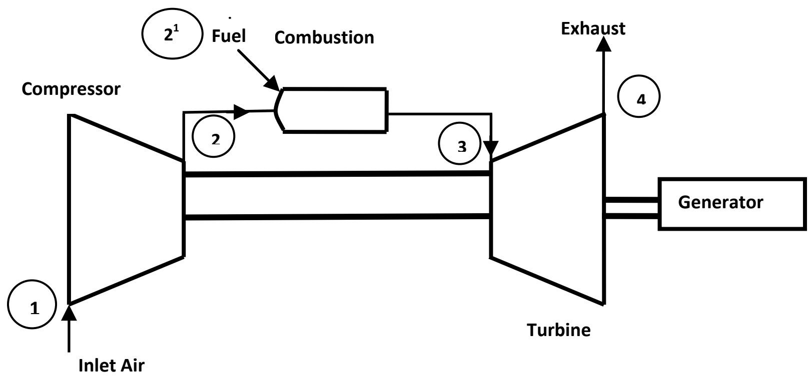

Figure1- the open-loop gas-turbine power plant

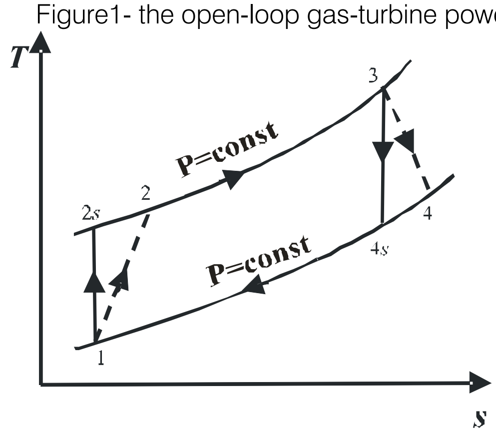

Figure2- T-s diagram of the actual open cycle gas turbine plant

The thermodynamic analysis of the gas turbine plant has been done by treating each component of the system as a control volume at steady state. This implies that the components experience no changes in their mass, energy, entropy, volume and exergy content. Hence, the amount of exergy entering the system in all forms (heat, work, mass transfer) must be equal to the amount of exergy leaving the system plus the exergy destroyed. A general exergy-balance equation, applicable to any component of a thermal system may be formulated by utilizing the first and second laws of thermodynamics (Mahamad and Mofid, 2005). The thermo-mechanical exergy stream may be decomposed into its thermal and mechanical components so that the balance in rate form gives

$$\dot{E}_i^m - \dot{E}_e^m = \left(\dot{E}_i^T - \dot{E}_e^T\right) - \left(\dot{E}_i^P - \dot{E}_e^P\right) \qquad (1)$$

where the subscripts i and e represent inlet and exit states; $\dot{E}^m$ is the exergy of the flow stream, $\dot{E}^T$ is the thermal component of the exergy stream; $\dot{E}^P$ is mechanical component of the exergy stream; the term on the left –hand side of the equation represent the change in exergy of the flow stream, the first and second terms on the right-hand side of the equation represent the changes in the thermal and mechanical components of the exergy stream, respectively.

The thermal and mechanical components of the exergy stream, assuming an ideal gas with constant specific heat, may be written, respectively, as

$$\dot{E}^T = \dot{m}c_p\left[\left(T - T_0\right) - T_0 \ln\frac{T}{T_0}\right] \quad (2)$$

and

$$\dot{E}^P = \dot{m}RT_0 \ln\frac{P}{P_0} \quad (3)$$

where P_0 and T_0 are the pressure and temperature, respectively, at standard state; $\dot{m}$ is the mass flow rate of the working fluid; R is the gas constant; c_p is the specific heat at constant pressure.

The exergy change of a system during a process is equal to the difference between the net exergy transfer through the system boundary and the exergy destroyed within the system boundaries as a result of irreversibilities. The exergy destroyed is proportional to the entropy generated and is positive for all actual processes. Hence, the general exergy equation applicable to all the components of the gas turbine plant may be written, utilizing the decomposition defined in equation (1) as follows:

$$\dot{E}^W = \dot{E}^{CHE} + \left(\sum_{inlet}\dot{E}_i^T - \sum_{exit}\dot{E}_e^T\right) + \left(\sum_{inlet}\dot{E}_i^P - \sum_{exit}\dot{E}_e^P\right) + T_0\left(\sum_{exit}\dot{S}_e - \sum_{inlet}\dot{S}_i + \frac{\dot{Q}_{CV}}{T_{in,CV}}\right) \quad (4)$$

where $\dot{E}^W$ $\dot{W}$ represents the exergy rate of power output; the term $\dot{E}^{CHE}$ denotes the rate of exergy flow of fuel in the plant; $\dot{S}$ is the entropy transfer rate; $T_{in,CV}$ is the temperature of the source from which the heat is transferred to the working fluid; the fourth right-hand term is the exergy destroyed in the component; and $\dot{Q}_{CV}$ in the fourth right-hand term denotes the heat transfer rate between the component and the environment.

In heat engines, such as the Brayton cycle considered, the exergy input to the system is the difference between the exergy of the positive heat interaction between the system and the high temperature thermal source, and that of the negative heat interaction between the system and the surroundings, the recovered exergy in the process is the network of the reversible heat engine cycle (Oko, 2008). The exergy destroyed in the cycle is the sum of the exergy destructions of the processes that compose the cycle. Hence, the exergy-balance equations for each component in the gas turbine power plant can be derived from the general exergy balance equation given in equation (4). The exergy destroyed during each process is calculated separately and then summed up as the total exergy destruction in all the processes in the cycle.

The exergy-balance equations and the exergy destroyed during each process and for the whole plant are written as follows:

$$\dot{E}_{D_{AC}} = T_0\left(\dot{S}_2 - \dot{S}_1\right) = \dot{m}T_0\left[c_{p1-2}\ln\left(T_2/T_1\right) - R\ln\left(P_2/P_1\right)\right] \quad (5a)$$

$$\dot{E}^{WAC} = \left(\dot{E}_1^T - \dot{E}_2^T\right) + \left(\dot{E}_1^P - \dot{E}_2^P\right) + T_0\left(\dot{S}_2 - \dot{S}_1\right) \quad (5b)$$

Combustion chamber:

$$\dot{E}_{D_{CC}} = T_0\left(\dot{S}_3 - \dot{S}_2 + \dot{S}_{2^1} + \frac{\dot{Q}_{2-3}}{T_{in,CC}}\right)$$

$$\dot{m}T_0\left[\left(c_{p2-3}\ln\left(T_3/T_2\right) - R\ln\left(P_3/P_2\right)\right) + \left(c_{p2^1}\ln\left(T_{2^1}/T_0\right) - R\ln\left(P_{2^1}/P_0\right)\right) + \frac{c_{p2-3}\left(T_3 - T_2\right)}{T_{in,CC}}\right] \text{--------} \quad (6a)$$

$$\dot{E}^{CHE} + \left(\dot{E}_2^T + \dot{E}_{2^1}^T - \dot{E}_3^T\right) + \left(\dot{E}_2^P + \dot{E}_{2^1}^P - \dot{E}_3^P\right) + T_0\left(\dot{S}_3 - \dot{S}_2 + \dot{S}_{2^1} + \frac{\dot{Q}_{2-3}}{T_{in,CC}}\right) = 0 \quad (6b)$$

Gas Turbine:

$$\dot{E}_{D_{GT}} = \dot{m}T_0\left[c_{p3-4}\ln\left(T_4/T_3\right) - R\ln\left(P_4/P_3\right)\right] \quad (7a)$$

$$\dot{E}^{WGT} = \left(\dot{E}_3^T - \dot{E}_4^T\right) + \left(\dot{E}_3^P - \dot{E}_4^P\right) + T_0\left(\dot{S}_3 - \dot{S}_4\right) \quad (7b)$$

Exhaust:

$$\dot{E}_{D_{EXH}} = T_0\left[\left(\dot{S}_4 - \dot{S}_1\right) + \frac{\dot{Q}_{4-1}}{T_0}\right] = \dot{m}T_0\left[\left(c_{p4-1}\ln\left(T_4/T_1\right) - R\ln\frac{P_4}{P_1}\right) + \frac{\left(c_{p4-1}\left(T_4 - T_1\right)\right)}{T_0}\right] \quad (8)$$

where $\dot{E}_{D_{AC}}, \dot{E}_{D_{CC}}, \dot{E}_{D_{GT}}$ and $\dot{E}_{D_{EXH}}$ represent the exergy destroyed in the air compressor, combustion chamber, gas turbine, and exhaust, respectively; $\dot{E}^{WAC}$ and $\dot{E}^{WGT}$ represent the exergy flow rate of the power output from the air compressor and the gas turbine, respectively; $\dot{E}^{CHE}$ is the exergy flow rate of fuel in the combustion chamber.

1. *Second-law efficiency of the gas turbine power plant*

Since exergy is more valuable than energy according to second law of thermodynamics, it is useful to consider both input and output from the plant in terms of exergy. From the above, the general definition of the exergy or second-law efficiency for a system may be written as

$$\eta_{II} = \frac{Exergy\ recovered}{Exergy\ supplied} = 1 - \frac{Exergy\ destroyed}{Exergy\ supplied} \quad (9)$$

Hence, the second-law efficiency of the gas turbine power plant under study is evaluated for the various components and for the overall plant from the following equations

Air compressor:

$$\eta_{II,AC} = 1 - \frac{\dot{E}_{D_{AC}}}{\dot{E}^{WAC}} \quad (10)$$

Combustion chamber:

$$\eta_{II,CC} = 1 - \frac{\dot{E}_{D_{CC}}}{\dot{E}^{CHE}} \quad (11)$$

Gas turbine:

$$\eta_{II,GT} = 1 - \frac{\dot{E}_{D_{GT}}}{\dot{E}^{WGT}} \quad (12)$$

Overall plant:

$$\eta_{II,PLANT} \quad \frac{\dot{E}^{WPLANT}}{\dot{E}^{CHE}} \quad (13)$$

Where $\dot{E}^{WPLANT}$ is the net power output from the plant?

2. *Power-to-Heat ratio and Specific Fuel Consumption (SFC)*

The Power –to-Heat ratio for the simple cycle is given by

$$R_{PH} = \frac{\dot{E}^{WPLANT}}{\dot{Q}_{2-3}} \quad (14)$$

where $\dot{Q}_{2-3}$ is the process heat supply rate.

The Specific Fuel Consumption (*SFC*) for the cycle is given by

$$SFC = \frac{3600 f}{\dot{E}^{WPLANT}} \quad (15)$$

where *f* is the fuel-air ratio.

III. Results and Discussion

Table 1 contains a record of the online data collected for the running power plant. The mass flow rates, temperatures and pressures were obtained directly from the speedtronics control system. The reference temperature and pressure were taken as $25°C$ and 1.0132bar, respectively, at relative humidity of 60%.

Table 1 Operating data for the 33-MW gas turbine power plant

S/N	Operating parameter	Value	Unit
1	Mass flow rate of air through compressor	136.5	kg/s
2	Temperature of inlet air to compressor	302	$°K$
3	Pressure of inlet air to compressor	0.10132	*MPa*
4	Outlet temperature of air from compressor	603	$°K$
5	Outlet pressure of air from compressor	0.835	*MPa*
6	Fuel-gas(natural gas) mass flow rate	2.80	kg/s
7	Fuel- air ratio at full load(on mass basis)	0.02	-
8	Inlet Temperature of fuel-gas	302	$°K$
9	Inlet pressure of fuel-gas	0.2279	*MPa*
10	Inlet temperature to gas turbine	1087	$°K$
11	Exhaust gas temperature	644	$°K$
12	Exhaust gas pressure	0.1032	*MPa*

The exergy flow rates at the inlet and outlet of each component of the plant were evaluated based on the values of measured properties such as pressure, temperature, and mass flow rates at various states. These quantities are used as input data to the computer program written to perform the simulation of the performance of the components of the gas turbine power plant and the overall plant. The values obtained for the chemical, thermal and mechanical exergy flow rates at various state points in the gas turbine plant are shown in Table 2.

An exergy balance for the components of the gas turbine plant and of the overall plant is at this point performed and the net exergy flow rates crossing the boundary of each component of the plant, together with the exergy destruction in each component are calculated and are as shown in Table 3. The product of a component corresponds to the added exergy whereas the resource to the consumed exergy (Mahamad and Mofid, 2005). The sum of the exergy flow rate of products, resources and destruction equals zero for each component. Hence, for each component, the sum of the values of the thermal and mechanical exergy components and the exergy destruction are substituted in the respective exergy balance equation and equated to the value of the output exergy as shown in the table.

Table 2 Exergy flow rates and entropy generation rates at various state points in the gas turbine plant

State	$\dot{m}(kg/s)$	$T(K)$	$P(MPa)$	$\dot{E}^T(MW)$	$\dot{E}^P(MW)$	$\dot{E}^{CHE}(MW)$	$\dot{S}(MW/K)$
1	136.5	302	0.10132	0.0452	0.0000	0.0000	0.0000
2	136.5	603	0.8350	14.6604	23.7966	0.0000	0.0144
2^1	2.80	302	0.2279	0.0021	0.7205	112.8035	0.0014
3	139.3	1087	0.8100	67.0999	23.9347	0.0000	0.0365
4	139.3	644	0.1075	18.3703	0.2117	0.0000	0.0015

This zero sum indicates that the exergy balance for the compressor, combustion chamber, the gas turbine and the overall plant are satisfied. The value of the total exergy destruction in the plant calculated from the addition of the individual exergy destructions in the components of the cycle is compared with the calculated value of the exergy destruction in the exhaust.

The exergy flow rate of the power output of the gas turbine power plant is found from the exergy balance to be 30.2 MW. The exergy flow rate of fuel in the combustion chamber is found to be 116.9MW. The total exergy destruction in the plant is found to be 69.83MW. The gas turbine is found to have the highest efficiency of 99.3%. The exergy efficiency of the combustion chamber is much lower than that of other

Table 3 Net exergy flow rates and exergy destruction in the gas turbine plant

Component	$\dot{E}^W(MW)$	$\dot{E}^{CHE}(MW)$	$\dot{E}^T(MW)$	$\dot{E}^P(MW)$	$\dot{E}_D(MW)$
Air Compressor	42.5290	0.0000	13.2241	24.9533	4.3515
Combustion Chamber	0.0000	116.8655	50.9338	0.6106	65.0313
Gas Turbine	72.7329	0.0000	47.4040	24.8762	0.4527
Plant	30.2	116.8655	16.7539	0.5335	69.8355
Exhaust	0.0000	0.0000	0.0000	0.0000	81.9193

plant components due to the high irreversibility in this section. Its value is calculated as 44.3%. The exergy efficiency of the axial flow air compressor is calculated as 89.7%. The exergy efficiency of the overall plant at compressor inlet air temperature of $29°C$ and turbine inlet temperature of $1087K$ is found to be 25.8%.

The Grassmann diagram of the Brayton cycle power plant is shown in Figure 3. It shows the percentage exergy input and exergy loss in each device and the exhaust based on the results of the exergy analysis. Compared with other components of the power plant, the largest amount of the total exergy supplied in the plant is destroyed in the combustion chamber, the least exergy loss found in the gas turbine. It is also shown that about 43.7% of the total inlet exergy flow in the plant is destroyed and rejected in the exhaust to the atmosphere.

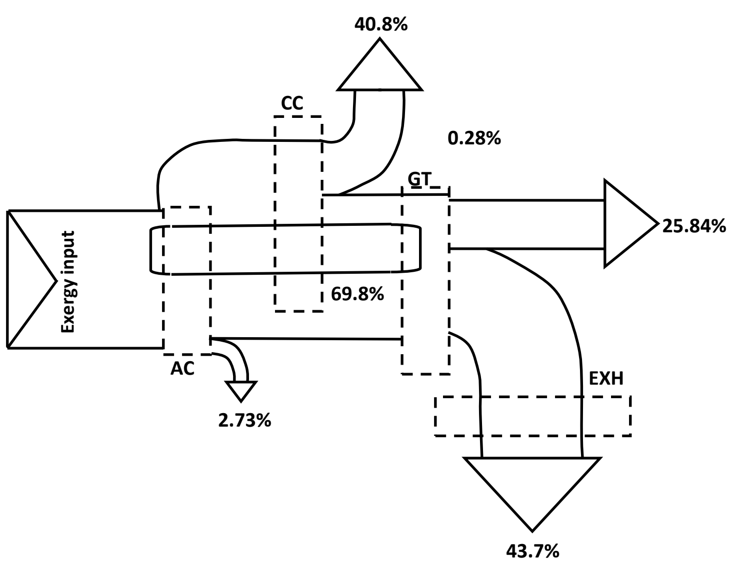

Figure 3- Grassmann diagram for the simple Brayton cycle

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The simulation of the performance of plant and components was done by varying the air inlet temperature: $15-45°C$; and the turbine inlet temperature: $1087-1800°K$, respectively. The computer program for the simulation under the conditions stated above and the results of the simulation are presented in Appendix A. Figure 4 compares the second-law efficiencies of the air compressor, combustion chamber, gas turbine and the overall plant when the ambient temperature increases. The second-law efficiencies of the plant and the combustion chamber are found to decrease more significantly with increase in the ambient temperature than the air compressor and the gas turbine, as shown in the figure. The simulation result reveals a 3.5%, 8.4%, 1.2%, and 0.07% decrease in the efficiencies of the plant, combustion chamber, air compressor, and gas turbine, respectively, for a 66% increase in the ambient temperature.

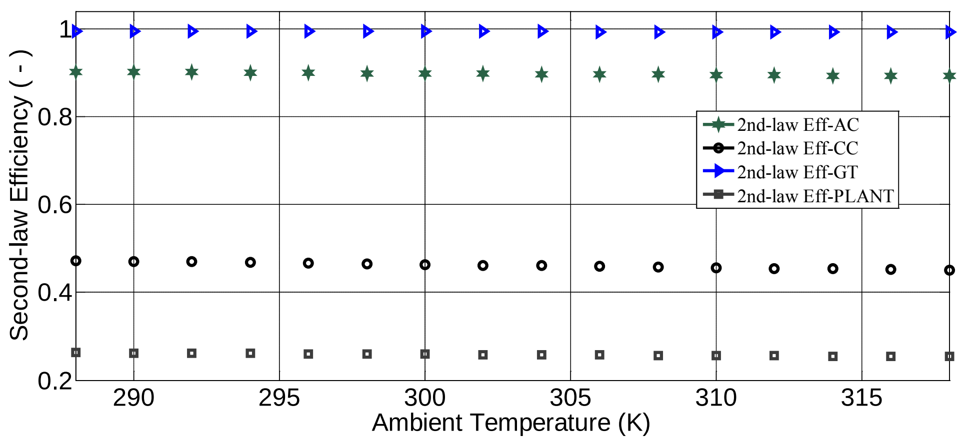

Figure4- Change in second-law efficiency with Ambient Temperature Variation

The second-law efficiency of the plant is also found to depend significantly on a change in turbine inlet temperature. Figure 5 shows that the second-law efficiency of the plant increases steadily as the turbine inlet temperature increases. The simulation result shows that the second-law efficiency of the power plant increases by about 24% for a 39% increase in the turbine inlet temperature.

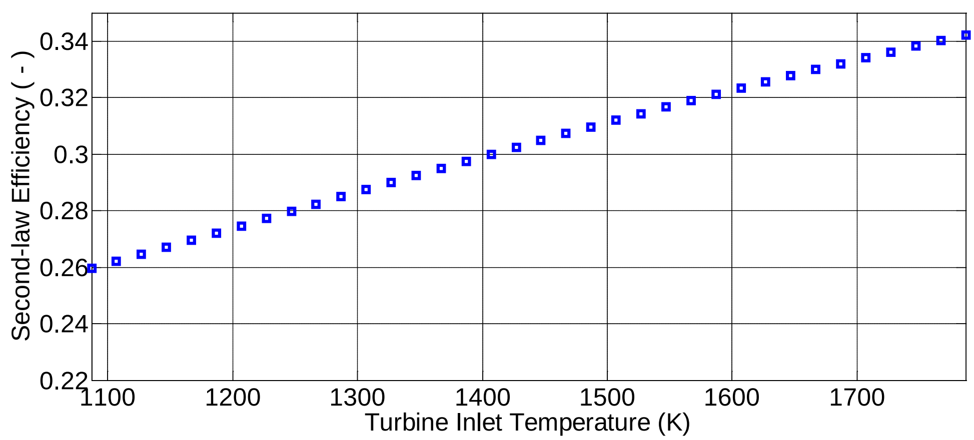

Figure5- Change in Second –Law Efficiency of Plant with Turbine Inlet Temperature Variation

The specific fuel consumption and power-to-heat ratio of the gas turbine plant were also found to change significantly with the turbine inlet temperature variation. Figure 6 shows that the power-to-heat ratio increases steadily with increase in the turbine inlet temperature. On the other hand, the specific fuel consumption decreases with increase in turbine inlet temperature. Hence, fuel energy is saved and power output from the plant enhanced as the turbine inlet temperature is increased.

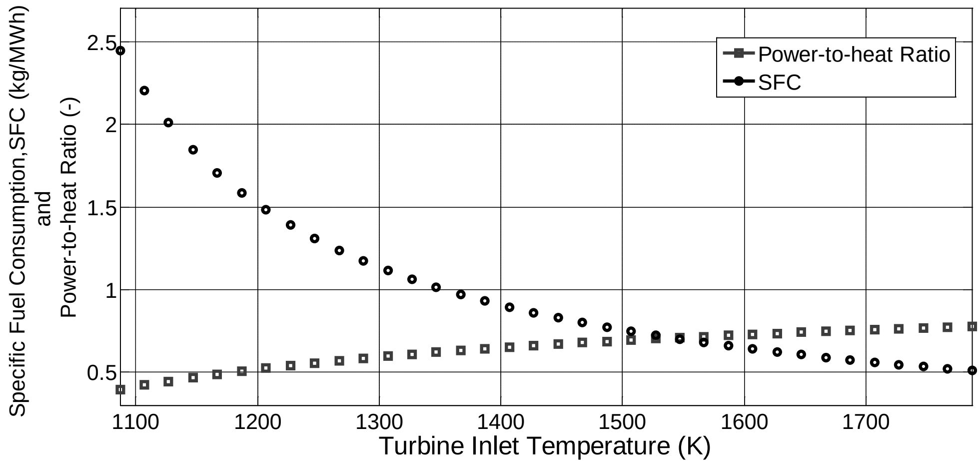

Figure6- Change in Specific Fuel Consumption and Power-to-Heat Ratio with Turbine Inlet Temperature variation

IV. CONCLUSION

An exergy analysis of a power generation gas turbine plant has been done. Exergy balance applied to each of the major components of the plant and to the overall plant reveals the amount of the total exergy generation and exergy destruction in the plant. The results from the gas turbine plant simulation reveal that the exergy destruction, exergy efficiency, exergy flow rate of the power output, power-to-heat ratio and the specific fuel consumption depend on ambient temperature and turbine inlet temperature.

V. ACKNOWLEDGEMENT

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Designing & Testing of Rectangular Micro strip antenna operating at 2.0 GHz using IE3D

By Er Nitin Agarwal, Dr.D.C.Dhubkarya, Er Rinkesh Mittal
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Abstract- This paper describes the design and fabrication techniques of rectangular microstrip patch antennas operating at 2.0 GHz. Considerable emphases are placed on the designing of rectangular microstrip antenna and antenna results through IE3D software. The design considerations are given for probe feed rectangular microstrip antenna operating at a frequency of 2.0 GHz. In this paper particular attention is paid to the measurement of Return losses and Band Width of the RMSA with the help of VSWR of the designed antenna.

Classification: GJRE-F FOR Classification: 100501

DESIGNING TESTING OF RECTANGULAR MICRO STRIP ANTENNA OPERATING AT 2.0 GHZ USING IE3D

Strictly as per the compliance and regulations of:

Designing & Testing of Rectangular Micro strip antenna operating at 2.0 GHz using IE3D

Er Nitin Agarwal[1], Dr.D.C.Dhubkarya[2], Er Rinkesh Mittal[3]

Abstract-This paper describes the design and fabrication techniques of rectangular microstrip patch antennas operating at 2.0 GHz. Considerable emphases are placed on the designing of rectangular microstrip antenna and antenna results through IE3D software. The design considerations are given for probe feed rectangular microstrip antenna operating at a frequency of 2.0 GHz. In this paper particular attention is paid to the measurement of Return losses and Band Width of the RMSA with the help of VSWR of the designed antenna.

I. Introduction

A microstrip patch antenna consists of a very thin metallic patch placed a small fraction of a wavelength above a conducting ground-plane. The patch and ground-plane are separated by a dielectric. The patch conductor is normally copper and can assume any shape, but simple geometries generally are used and this simplifies the analysis and performance prediction. The patches are usually photo etched on the dielectric substrate. The substrate is usually non-magnetic. The dielectric constants of the substrate are normally in the range of 2.2 < ε_r < 12, which enhances the fringing fields that account for radiation, but higher values may be used in special circumstances. Due to its simple geometry, the rectangular patch is the most commonly used microstrip antenna. It is characterized by its length L, width W and thickness h, as shown in Figure 1.

The simplest method of feeding the patch is by a coplanar microstrip line, also photo etched on the substrate. Coaxial feeds are also widely used. The inner conductor of the coaxial-line (sometimes referred to as a probe) is connected to the radiating patch, while the outer conductor is connected to the ground-plane, as shown in Figure 2.

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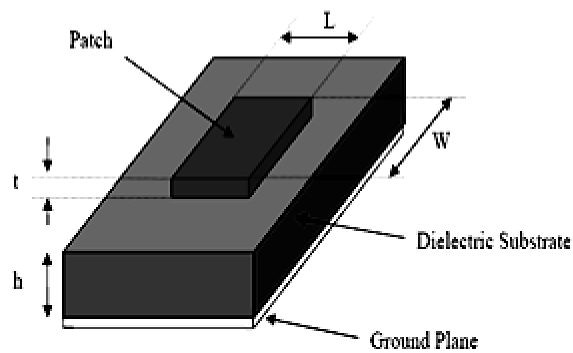
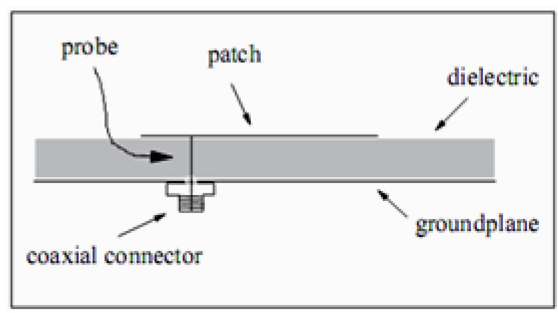


"Figure1 ." A rectangular microstrip patch antenna .



"Figure2." A patch excited using a coaxial probe.

The antenna described here is a probe-fed rectangular microstrip patch antenna designed to operate at a frequency of 2.0 GHz.

II. A Probe-feed Rectangular Patch Antenna

The first design step is to choose a suitable dielectric substrate of appropriate thickness. Many manufacturers offer suitable substrates in various thicknesses and in a variety of claddings. For this antenna, bandwidth and radiation efficiency considerations dictate that the antenna be fabricated on a relatively thick substrate of low relative permittivity. The dielectric loss is proportional to the loss tangent, and values less than about 0.005 are suitable. Conductor losses are not a problem at this frequency, as the skin depth is about 2 μm for copper at 2.0 GHz. The arrangement of a rectangular shaped microstrip antenna is given in Figure 1& 2. It consists of patch, substrate, ground plane and feeding point. A patch is a two-ground plane and feeding point. A patch is a two-dimensional antenna element, which is often rectangular in shape. It is of a very thin thickness (t) of metallic strip on top of a material known as the substrate with thickness h (h « λo), usually 0.003λo≤h≤0.05λo, where λo is free space wavelength above a ground plane. For rectangular patch, the length L of the element is usually λo/3<L<λo/2. The strip (patch) and the ground plane are separated by a dielectric (substrate). Microstrip antennas have a very high antenna quality factor (Q). This factor represents the losses associated with the antenna and a large quality factor leads to narrow bandwidth and low efficiency. Quality factor can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by the use of photonic band gap structures .Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements. The patch is generally square, rectangular, circular, triangular, and elliptical or some other common shapes. Microstrip antennas have narrow bandwidth, typically 1-5%, which is the major limiting factor for the widespread application of these antennas. Increasing the bandwidth of MSA has been the major thrust of researches in this field.

III. Feeding Methods

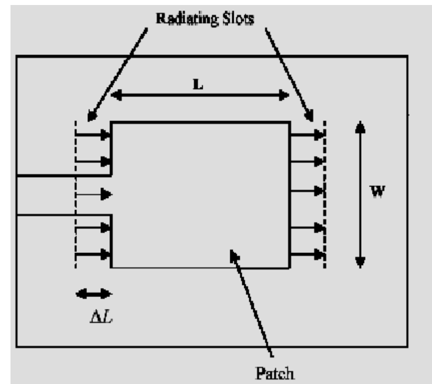
There are many configurations that can be used to feed microstrip antennas. The four most popular feeding are the microstrip line, coaxial feed, aperture coupling and proximity coupling. The feeding technique we are using here is coaxial probe feeding.

IV. Analyses and Modeling of RMSA Parameters

1. *Effective length, Resonant frequency & Effective width*

Three methods of analysis are commonly used to calculate microstrip antenna (MSA) parameters. These are transmission line model, cavity model, and full wave analysis. It is useful to model the microstrip antenna as a transmission line. This model is the simplest of all and it gives good physical insight. It represents the MSA by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non homogeneous line of two dielectrics, typically the substrate and air. An effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The expression for ε_{reff} is given by

eq(1): $$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \quad (1)$$



"Figure 3." Side view of Rectangular microstrip antenna.

In order to operate in the fundamental TM10 mode, the length of the patch must be slightly less than λ/2 where λ is the wavelength in the dielectric medium and is equal to λo/√εreff where λo is the free space wavelength. In Fig.3. the MSA is represented by two slots, separated by a transmission line of length L and open circuited at both ends. Along the width of the patch, the voltage is max and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane as in Fig.3.

The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by eq (2):

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (2)$$

So the effective length of the patch Leff now becomes:

$$L_{eff} = L + 2\Delta L \quad (3)$$

For a given resonance frequency fr, the effective length is given as:

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (4)$$

Where c is the speed of light. For a rectangular microstrip patch antenna, the resonance frequency for any TMmn mode is given as:

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$

(5)

Where m and n are modes along L and W respectively.

For efficient radiation, the width W is given as:

$$W = \frac{c}{2 f_r \sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)}} \quad (6)$$

2. *Input impedance and conductance*

4.2 Input impedance and conductance

The input impedance should be accurately known so that a good match between the element and the feed can be designed. The input impedance at the feed:

$$Z_{in}(x_0) = \frac{1}{G_r + G_m \cos(n\pi)} \cos^2(\beta x_0)$$

Where Gr is the self conductance given by the following three relations, depending on W/λo:

$$Gr = \frac{W^2}{90\lambda_0^2}, \; for W < 0.35\lambda_0$$

$$G_r = \frac{W}{120\lambda_0} - \frac{1}{60\pi^2}, \; for 0.35\lambda_0 \le W \le 2\lambda_0$$

$$G_r = \frac{W}{120\lambda_0}, \; for 2\lambda_0 \le W$$

and Gm is the mutual conductance between the patch ends. At resonance and Gr>>Gm then the input impedance becomes:

$$Z_{in}(x_0) = R_{in} = \frac{1}{G_r}\cos^2\left(\frac{\pi}{L}x_0\right) \quad (7)$$

3. *Return Loss and VSWR*

The return loss (RL) is a parameter which indicates the amount of power that is lost to the load and does not return as a reflection. As already known, waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match. Hence the return loss is a parameter similar to the VSWR to indicate how well the matching between the transmitter and the antenna has taken place. The RL is defined as

$$RL = -20\log 10[\Gamma] dB \quad (8)$$

Where Γ is input reflection coefficient and it is a measure of reflected signal at the feed-point of the antenna.

4. *Bandwidth*

The most serious limitation of the microstrip antenna is its narrow BW. The BW could be defined in terms of its VSWR or input impedance variation with frequency or in terms of radiation parameters. For the circularly polarized antenna, BW is defined in terms of the Axial Ratio. VSWR is a very popular parameter for determining the BW of a particular antenna configuration (1≤ VSWR ≤ 2) as an acceptable interval for determining the BW of the antenna.BW is presented more concisely as a percentage where:

$$BW\% = \frac{\Delta f}{f_o} \times 100\% \quad (9)$$

Where Δf is the width of the range of acceptable frequencies, and fo is the resonant frequency of the antenna.

The expressions for approximately calculating the percentage BW of the (RMSA) antenna in terms of patch dimensions and s

$$\%BW = \frac{A \times h}{\lambda_o \sqrt{\in_r}} \sqrt{\frac{W}{L}} \quad (10)$$

Where A is constant: ubstrate parameters is given by:

A = 180 for

$$\frac{h}{\lambda_o \sqrt{\in_r}} \le 0.045$$

A = 200 for

$$0.045 \le \frac{h}{\lambda_o \sqrt{\in_r}} \le 0.075$$

A = 220 for

$$\frac{h}{\lambda_o \sqrt{\in_r}} \ge 0.07$$

With an increase in W, bandwidth increases. However, W should be taken less than λ to avoid excitation of higher order modes. The BW of the (MSA) can also nversely proportional to its quality actor Q and is given by.

$$BW = \frac{(VSWR - 1)}{Q\sqrt{VSWR}} \quad (11)$$

The BW is usually specified as frequency range over which VSWR ≤ 2.

V. Design Consideration

To achieve the requirements, design examples are considered for the rectangular microstrip antenna which is designed to operate at 2.0GHz as center frequency. The calculations are made step by step. We are taking glass epoxy as a dielectric material with (εr =4.2 & h =1.6mm), loss tangent =0.0005, operating frequency=2.0 GHz.

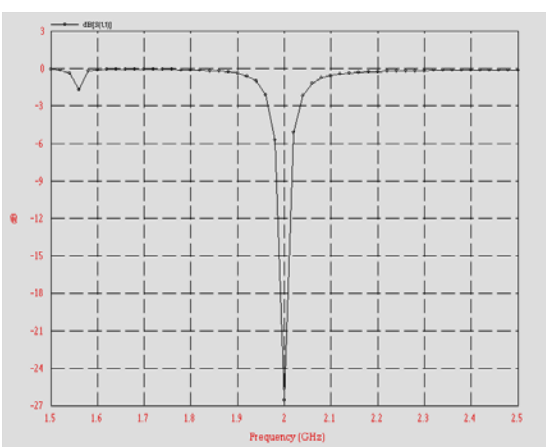
- Equation (6) gives the width of the RMSA W = 46.5mm
- Equation (1) gives the eff. dielectric constant εreff=3.946 • Equation (4) gives the effective length Leff =37.19mm
- Equation (2) gives the length extension ΔL=0.845 mm
- Equation (3) gives the actual length

L = Leff -2ΔL then L=35.5mm

VI. Simulation and Results Using IE3D

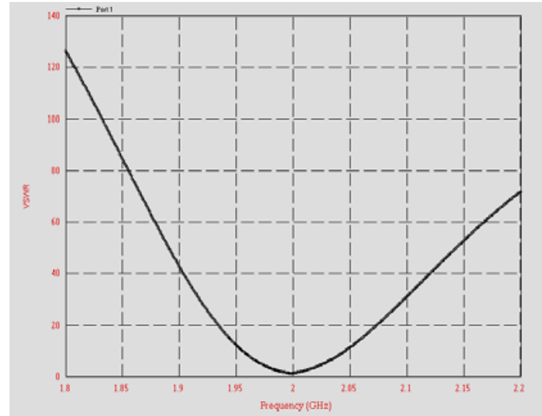
The MSA antennas specified above has been analyzed by the zeland IE3D evaluation version 12.32. For RMSA design used glass epoxy which is Teflon based, microstrip board with dielectric constant 4.2 and the substrate height is 1.6 mm, and loss tangent is 0.005. The properties of antenna such as bandwidth, S-Parameter has been investigated and compared between different optimization scheme and theoretical results.

The feed point of RMSA i.e. (X_f, Y_f) is to be find out from the IE3D where the return losses come below to the -10DB. So this result the feed point comes (24, 25) where the value of R.L is about -26.61 DB at 2 GHz shown in fig 4.



"Figure 4." Simulated R.L of RMSA at 2.0 GHz

The simulated frequency range for measurement of VSWR < 2 are from 1.988 GHz to 2.009 GHz, thus resulting in a bandwidth of 21 MHz. The VSWR Plot from IE3D is shown in fig 5.

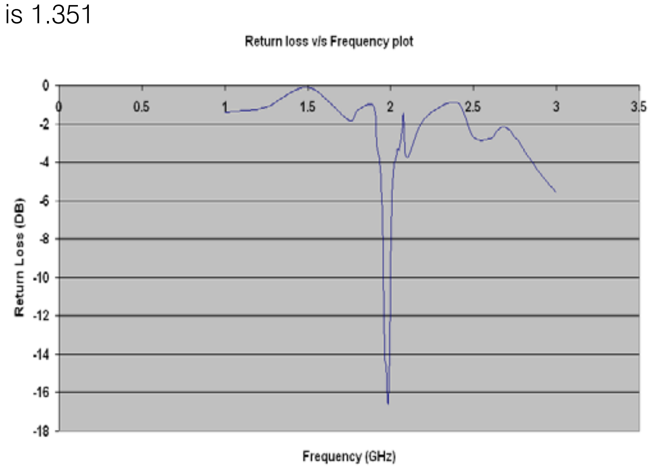


"Figure 5." Simulated VSWR of RMSA at 2.0 GHz

VII. Tested Results from Designed Antenna

For practically measurement of return loss of the designed rectangular microstrip antenna, it has been connected to the spectrum analyzer through coaxial cable. This spectrum analyzer (make: ROHDE & SCHWARZ) having a capability of testing antennas with resonant frequencies ranging from 9 KHz – 3GHz.

From the result on spectrum analyzer, it is clear that at the 1.989 GHz frequency, the return losses are (-16.5) dB. The center frequency 1.989 GHz is very close to desired frequency of operation (2.0 GHz). So the designed antenna is working properly and using the equation no. the VSWR of the antenna at this frequency is 1.351



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A Non Proportional Sharing Power Flow Tracing Based on Bus Power Balance Equations

By Roozbeh Morsali, Abdolreza Sheikholeslami
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Abstract- Using proportional sharing assumption in power flow tracing has always been a controversial issue because there is no proof to accept or deny such an assumption. In this paper, we propose tow new method one based on proportional sharing and the other based on bus power equations and network's impedance matrix to solve power flow tracing problems. And we use these solutions to find generation units and consumer loads shares in transmitting power of each line of the network. Both methods are able to handle loop flow and can be applied for both active and reactive power flow tracing. The case study on IEEE 24 bus reliability test system (RTS) shows that the proposed tracing methods are effective and accurate in transmission cost allocation and other tracing problems. Also a comparison between these methods has been made to illustrate the efficiency of proportional sharing assumption.

Keywords: power flow tracing, transmission cost allocation, proportional sharing assumption, bus power equations.

Classification: GJRE-F FOR Classification: 090699

A NON PROPORTIONAL SHARING POWER FLOW TRACING BASED ON BUS POWER BALANCE EQUATIONS

Strictly as per the compliance and regulations of:

A Non Proportional Sharing Power Flow Tracing Based on Bus Power Balance Equations

Roozbeh Morsali[1], Abdolreza Sheikholeslami[2]

Abstract-- Using proportional sharing assumption in power flow tracing has always been a controversial issue because there is no proof to accept or deny such an assumption. In this paper, we propose tow new method one based on proportional sharing and the other based on bus power equations and network's impedance matrix to solve power flow tracing problems. And we use these solutions to find generation units and consumer loads shares in transmitting power of each line of the network. Both methods are able to handle loop flow and can be applied for both active and reactive power flow tracing. The case study on IEEE 24 bus reliability test system (RTS) shows that the proposed tracing methods are effective and accurate in transmission cost allocation and other tracing problems. Also a comparison between these methods has been made to illustrate the efficiency of proportional sharing assumption.

Keywords- power flow tracing, transmission cost allocation, proportional sharing assumption, bus power equations.

I. Nomenclature

Sg_i	Set of generation units connected to bus *i*.
Sl^{in}_i	Set of lines which inject power to bus *i*.
Sd_i	Set of loads consuming power at bus *i*.
Sl^{out}_i	Set of lines carrying out power from bus *i*.
PG_g	Active power generated by generator *g*.
PL_l	Active power flow of line *l*.
PD_d	Active power consumed by load *d*.
N_l	Number of lines.
N_g	Number of generation units.
N_b	Number of network buses.
GSD	Generation Share in Demands.

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II. Introduction

Various changes in the socio-economic structure of power systems lead to the drastic changes in the technical aspects of power system control and management, after the era of restructuring. Nowadays, power systems are totally market driven in most of countries all around the world. In a vertically integrated system the answer of this question: "what is the share of a certain unit in the power flow of a particular line or in the demand power of a particular load" is of a little importance. This always referred as power flow tracing (PFT) problem, which is one of the challenging issues in restructured power systems and has been received a great attention during these years.

In order to find a practicable method to allocate the cost of transmission between different market participants, different methods have been applied, each with particular criteria or assumptions. Reviewing the literatures, one can deduce that these methods can be classified into two major categories. The methods of the first category do not really follow the power flow from generating units into the loads. Following a market clearing process, these methods always find the share of different participants in cost of a certain transmission line using sensitivity factors. These methods always solve the problem very fast without engaging in time and memory consuming processes like matrix inversion, so they are suitable for bulky power systems. The methods which use different form of generation shift factors (GSF) belong to this category. [1] use GSFs to solve the tracing problem. The main question about the effectiveness of such methods is: "which one is more interesting to us when we are about to solve the tracing problem? The *"impact* of change in generation of a unit on the flow of a certain line or its *share*?" Answering this question logically, some new approaches were proposed in literatures [1]-[5] based on GSFs. Another defectiveness of such methods is due to their dependence on slack bus.

The methods of the second category use different tricks and some times, simplifying assumptions to trace the real share of different participants in power flow of different lines. This category contains the topological [6], [7] and the up-stream and down-stream looking algorithms, which all

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assume proportional contribution factors. The method of up-/down-stream tracing for example was used in [1], [8]. A topological-based method was presented in [9], which uses extended incidence matrix (EIM). Though the authors pointed out that the method does not assume proportional sharing, the method does not consider any difference between different sources of power injection to a bus, when analyzing their shares in bus outflows. This is the main assumption in proportional sharing methods instead of considering physical relations between different in-/outflows.

In [10], the authors used network *Zbus* and applied the circuit laws to draw a relation between the flow of a line and the injected current from different network buses. Though the method is categorized in first category, application of the circuit law instead of proportional sharing assumption is a very interesting aspect of this work.

In this paper two different methods of power flow tracing are proposed and compared. The first method uses the proportional sharing assumption to draw the relations between power in- and out-flows of network buses from power balance equation of the network buses. The second method uses the idea of power balance equation of the first method, but uses the circuit laws to draw the mentioned relations. Both methods can trace the active and reactive power flows from generating units to loads, even in the case of networks with loop flows. The main advantage of proposed methods is the fact that they both trace the actual share of different participants in power flow of network lines rather than their impact on these flows. Another virtue of the presented methods is the way they handle the loss issues in tracing process. The problem appears since the power which is extracted in receiving end of a line is not the same as injected one due to line losses. [9] For example, added the half value of active and reactive losses of each line to the load value of two end of the line. This is a good approximation, but it slightly changes the results of tracing algorithm.

The rest of the paper is organized as follows. Section III gives an overview of proposed methods as well as the problem formulation for both methods. IEEE reliability test system (RTS) is presented as an illustrative example in section IV and the results of proposed methods are compared and in detail discussed. Conclusions are drawn in section V.

III. Proposed Nethods

In this section both methods are explained and their formulations are presented. In both methods we assume that the generation of different units and the load values are given.

1) *Proposed proportional sharing method*

Considering generating units, lines and transformers which are connected to bus *i*, one can write a simple equation for active power balance at this bus (1).

$$\sum_{g\in Sg_i} PG_g + \sum_{l\in Sl_i^{in}} PL_l = \sum_{d\in Sd_i} PD_d + \sum_{l\in Sl_i^{out}} PL_l \qquad (1)$$

Based on the proportional sharing assumption, there is no difference between different terms in left hand of equation (1). This equation combined with proportional sharing assumption leads to (2) for each line:

$$\sum_{g=1}^{Ng} u_{l,g} + \sum_{l'=1}^{Nl} w_{l,l'} = 1 \qquad (2)$$

Where $u_{l,g}$ is share of unit g in power flow of line *l*, When this unit is connected to the sending bus of line *l*.

$$u_{l,g} = \begin{cases} \dfrac{PG_g}{\sum\limits_{g\in Sg_i} PG_g + \sum\limits_{li\in Sl_i^{in}} PL_{li}} & g\in Sg_i\ ,\ l\in Sl_i^{out} \\ 0 & \text{other wise} \end{cases} \qquad (3)$$

$$w_{l,l'} = \begin{cases} \dfrac{PL_{l'}}{\sum\limits_{g\in Sg_i} PG_g + \sum\limits_{li\in Sl_i^{in}} PL_{li}} & l'\in Sl_i^{in}\ ,\ l\in Sl_i^{out} \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

Where $w_{l,l'}$ is the share of line *l'* in power flow of line *l*. There is out Nl^{put}_i equations of form of (2) for bus *i*, so we have *Nl* equations each for a certain line of the network. (3) and (4) are written based on proportional sharing assumption and determine the share of bus *i* in flows in power flow of the lines which transmit active power from this bus to others.

We now can express the power flow of each line in two different ways. Let us show them in two tables. Table I shows the share of each unit in power flow of each line (the variables we are about to find in tracing problem). Table II contains the shares which are mentioned earlier in (3) and (4).

Table I Share of Each Unit in Power Flow of Line L

	Gen. 1	Gen. 2	..	Gen. Ng
Line 1	$x_{1,1}$	$x_{1,2}$	..	$x_{1,Ng}$
Line 2	$x_{2,1}$	$x_{2,2}$	..	$x_{2,Ng}$
…	…	…	..	…
Line Nl	$x_{Nl,1}$	$x_{Nl,2}$	..	$x_{Nl,Ng}$

Table II Share of Each Unit and Line, Which is Directly Connected to Sending end of Line L in Power Flow of Line L

	Gen. 1	Gen. 2	Gen. Ng	L.1	L.2	L.Nl
Line 1	$u_{1,1}$	$u_{1,2}$	$u_{1,Ng}$	$w_{1,1}$	$w_{1,2}$	$w_{1,Ng}$
Line 2	$u_{2,1}$	$u_{2,2}$	$u_{2,Ng}$	$w_{2,1}$	$w_{2,2}$	$w_{2,Ng}$
…	…	…	…	…	…	…
L. Nl	$u_{Nl,1}$	$u_{Nl,2}$	$u_{Nl,Ng}$	$w_{Nl,1}$	$w_{Nl,2}$	$w_{Nl,Ng}$

Comparing these two tables, an equation can be written for the share of each generating unit in power flow of each line (5) (*Ng X Nl* equations). In order to understand (5), one can separate two terms of the right hand of this equation. $U_{l,g}$ is the direct share of unit g in power flow of line *l*, when they both connected to a same bus. The second term (summation) is the indirect share (of other units), carrying by the other lines to line *l*. The main advantage of (5) is that it can handle loop flows in the network.

$$x_{l,g} = u_{l,g} + \sum_{k=1}^{Nl} w_{l,k} . x_{k,g} \qquad (5)$$

For a certain unit there are *Nl* equations in form of (5), while this unit has *Nl* different shares in the flow of different lines. Let us write these equations for unit *g*:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{1,g} \\ x_{2,g} \\ \vdots \\ x_{Nl,g} \end{bmatrix} \qquad (6)$$

$$= \begin{bmatrix} u_{1,g} \\ u_{2,g} \\ \vdots \\ u_{Nl,g} \end{bmatrix} + \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,Nl} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,Nl} \\ \vdots & \vdots & \ddots & \vdots \\ w_{Nl,1} & w_{Nl,2} & \cdots & w_{Nl,Nl} \end{bmatrix} \begin{bmatrix} x_{1,g} \\ x_{2,g} \\ \vdots \\ x_{Nl,g} \end{bmatrix}$$

(6) is a set of *Nl* equations with *Nl* unknown variables. These equations can be solved easily using (7). In this equation X_g is a *Nl X1* vector and g^{th} column of the matrix $X_{(Nl\,X\,Ng)}$.

$$X_g = (eye_{Nl \times Nl} - W)^{-1} . U_g \qquad (7)$$

It should be noticed that only one matrix inversion is necessary, since this matrix does not change for different units. One can also solve (6) with a faster method, since matrix *Z* is a very sparse matrix. This leads to a lower solution time for a bulky power system. To allocate the share of each load in power flow of each line we can begin from (1) as starting point. Then we should rewrite (2), (3) and (4) in order to calculate share of bus utflows (consisting of loads and lines with outgoing power flow) in power flow of lines, which inject power into bus *i* . Let us show these shares in matrix $Y_{(Nl\,X\,Nd)}$.

Reactive power tracing formulation in this method is exact the same as active power case, so this part of formulation is excluded, but the results of reactive power tracing are also shown in section IV.

2) *Method of non proportional sharing*

The only change in this sub-section with respect to the previous one is replacing the proportional sharing assumption with Kirchhoff's circuit laws. As a result, (3) and (4) are not valid anymore. To calculate the share of inflows of bus *i* in power flow of the lines which transmit active power from this bus to the others, one can replace all the lines which carry power to this bus, with generating units (pseudo units) of the same value of active and reactive generation as the regarding lines active and reactive power inflows. Reminding network has a new Z_{bus} (Fig. 1). Let us call it $Z^{new}{}_{bus}$. It is not necessary to recalculate all the elements of this matrix. There is a simple modification method presented in power system analysis text books, like [11], that can be used to modify Z_{bus}. Besides, all the matrix entries are not necessary in the formulation. Considering all of the units and loads as current sources, voltage of different network buses is given as (8).

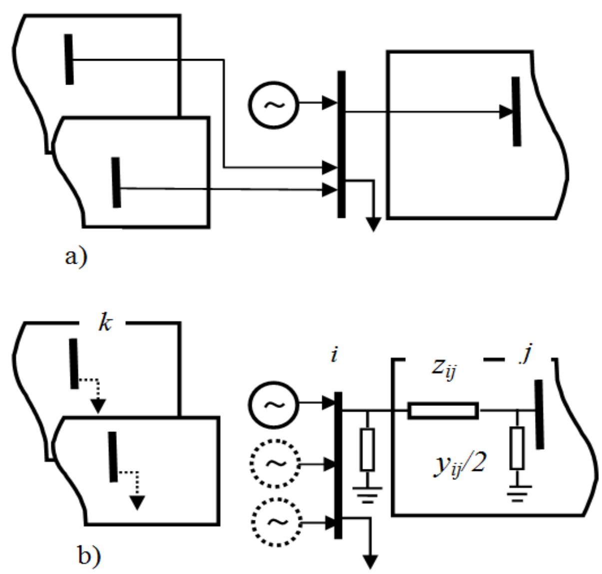

Fig1. (a) A Base power system, (b) Equivalent system

$$V_s = \sum_{k=1}^{Nb^{new}} Z_{s,k}^{new} . I_k \qquad (8)$$

The current trough line *ij* in Fig. 1 can be found using (9).

$$I_{ij} = (V_i - V_j) / z_{ij} + V_i .\, y_{ij} / 2 \qquad (9)$$

Substituting (8) in (9)

$$I_{ij} = \sum_{k=1}^{Nb^{new}} [\frac{Z_{i,k}^{new} - Z_{j,k}^{new}}{z_{ij}} + \frac{Z_{i,k}^{new} .\, y_{ij}}{2}] . I_k \qquad (10)$$

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In (10) the term which is written between brackets depends on network parameters and is therefore a constant value *(a_{ij})*, so

$$S_{ij} = V_i . I_k^* = V_i . \sum_{k=1}^{Nb^{new}} a_{ij}^* . I_k^* \qquad (11)$$

$$P_{ij} = \sum_{k=1}^{Nb^{new}} \Re(V_i . a_{ij}^* . I_k^*) \qquad (12)$$

Let us separate positive and negative effects of loads and generations on power flow of line *ij*.

$$P_{ij} = P_{ij}^{g+} + P_{ij}^{d+} + P_{ij}^{g-} + P_{ij}^{d-} \qquad (13)$$

Fig. 1 (b) shows that only units (and pseudo units) which are connected to bus *i* (in new network) have a positive effect on flow of line *ij*.

$$P_{ij}^{g+} = \Re(a_{ij}^* . V_i . I_i^{+*}) = \Re(a_{ij}^* . S_i^+) \qquad (14)$$

In (14) Si+ is total apparent power injected to bus *i* by the units which have positive effect on the flow of line *ij*. Let us separate the share of each unit (or pseudo unit) and each line in this flow

$$P_{ij}^{g+} = \sum_{g \in Sg_i} \Re(a_{ij}^* . S_g) + \sum_{l' \in Sl_i^{in}} \Re(a_{ij}^* . S_{l'}) \qquad (15)$$

$$u_{l,g} = \begin{cases} \dfrac{\Re(a_{ij}^* . S_g)}{P_{ij}^{g+}} & g \in Sg_i \, , \, l \in Sl_i^{out} \\ 0 & \text{other wise} \end{cases} \qquad (16)$$

$$w_{l,l'} = \begin{cases} \dfrac{\Re(a_{ij}^* . S_{l'})}{P_{ij}^{g+}} & l' \in Sl_i^{in} \, , \, l \in Sl_i^{out} \\ 0 & \text{other wise} \end{cases} \qquad (17)$$

Now the share of all units and lines which inject power into bus *i* in each outflow of this bus, are determined, and the share of other units which are not connected to this bus should be found. This problem is solved earlier in subsection III. A.

Again, the share of each load in power flow of each line should be calculated too. To do this, one can consider the network with all the lines which carry power from this bus to the others, replaced with loads (pseudo loads) of the same value of active and reactive consumption as the regarding lines active and reactive power outflows. A new Z_{bus} should be defined and this time the share of load and outflows in inflows of bus *i* can be found. Reactive power can be traced using this method either. It is sufficient to replace Â operator with Im and rewrite the equations.

As can be seen in this method and method which discussed earlier in sub-section III.A, two different equations are written for each line. One of them, which is used to find the units' shares in flow of each line, is written considering the line flow at sending end of the line, while the other one which is useful to find the loads' shares, considers flow of the receiving end of the line. It helps us divide the cost of line losses equally between units and loads without any simplifying assumption (like the method which was used in [18] to model line losses with two load at two end of the line) while solves the tracing problem precisely (see section II).

3) *Cost allocation among participants*

The power which transfers through a line comes from different units and finally feeds different loads, so it is sensible to divide the transmission cost of this line into two equal shares between these units and these loads. The share of unit *g* and load *d* in transmission cost of line *l* can be found using (18) and (19) respectively.

$$Cost_{g,l} = \frac{X_{l,g} * Cost_l}{2} \qquad \forall g \in Sg \, , l \in Sl \qquad (18)$$

$$Cost_{d,l} = \frac{X_{l,d} * Cost_l}{2} \qquad \forall d \in Sd \, , l \in Sl \qquad (19)$$

4) *Share of each unit in consumption of each load*

Considering the share of each unit in flow of each line *(X)*, one can find the share of each generating unit in consumption of each load (21).

$$\sigma_{d,g} = \frac{\sum_{l' \in Sl_i^{in}} X_{l',g} * PL_{l'} - \sum_{l \in Sl_i^{out}} X_{l,g} * PL_l}{\sum_{d' \in Sd_i} PD_d} \qquad \forall d \in Sd_i \qquad (20)$$

$$GSL_{i,g} = \begin{cases} \sigma_{i,g} & \sigma_{i,g} \geq 0 \\ 0 & \text{otherwise} \end{cases} \qquad (21)$$

IV. Case Study

The case studies are tested on the IEEE Reliability Test System (RTS1) which consists of 24 buses, 26 generators, and 17 loads (Fig. 2). System information has been extracted from [12]-[14]. The load profile corresponds to 6 PM of a Monday of a winter weekday. The capacities of lines 11–13 and 15–24 have been reduced from 500 MVA in [12] to 175 MVA. A one-hour time horizon is considered. The results of unit commitment algorithm considering DC and AC load flows are shown in Table III. Proposing a good method for transmission pricing is beyond the scope of this paper. Besides all the results cannot be included here, so for sake of comparison, a fixed cost of 10 $ is considered for each MW flow of each line in each hour and the results of transmission cost allocation are presented in different examples. Reactive power flow tracing results are excluded due to simplicity in concluding from results.

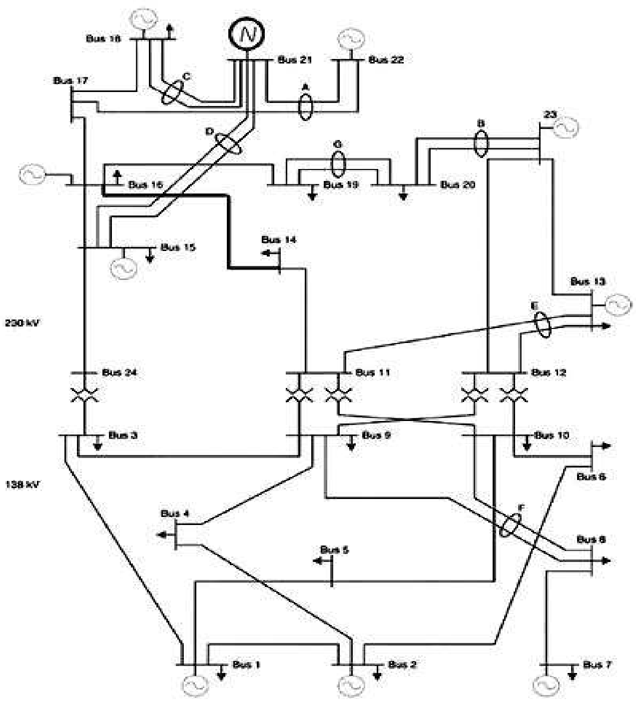

Fig. 2.IEEE Reliability Test System (RTS)

Table III Results of AC and DC Unit Commitment

Bus No	*Unit type*	*State*	*pg (MW) DC*	*Pg (MW) AC*	*Qg (MW) AC*
1	U20	On	0.00	0.00	0.00
1	U20	On	19.38	16.97	4.10
1	U76	On	76.00	76.00	-3.14
1	U76	On	76.00	76.00	-3.14
2	U20	Off	18.93	16.78	10.00
2	U20	Off	0.00	0.00	0.00
2	U76	On	76.00	76.00	30.00
2	U76	On	76.00	76.00	30.00
7	U100	On	100.00	99.08	18.68
7	U100	On	100.00	99.08	18.68
7	U100	On	100.00	99.07	18.68
13	U197	On	127.52	139.75	0.00
13	U197	On	127.52	139.75	0.00
13	U197	On	127.52	139.75	0.00
15	U12	On	11.03	12.00	1.11
15	U12	On	11.03	12.00	1.11
15	U12	On	11.03	12.00	1.11
15	U12	On	11.03	12.00	1.11
15	U12	On	11.03	12.00	1.11
15	U155	On	155.00	155.00	-30.00
16	U155	On	155.00	155.00	80.00
18	U400	On	400.00	400.00	178.98
21	U400	On	400.00	400.00	-17.26
23	U155	On	155.00	155.00	63.88
23	U155	On	155.00	155.00	63.88
23	U350	On	350.00	350.00	87.92

1) *Peak load, first method*

The method presented in sub-section III.A is used here to find the share of all of the units and loads in active power flow of each line.

Table IV Share of Each Unit in Total Transmission Cost and Transmission Prices for Each Unit, First Method

Bus No	*Unit type*	*US ($) DC*	*US ($) AC*	*UTP($/MW-h) DC*	*UTP ($/MW-h) AC*
1	U20	0.00	0.00	-	-
1	U20	37.33	30.74	1.92	1.81
1	U76	146.34	137.64	1.93	1.81
1	U76	146.34	137.64	1.93	1.81
2	U20	42.70	35.84	2.25	2.14
2	U20	0.00	0.00	-	-
2	U76	171.41	162.32	2.26	2.14
2	U76	171.41	162.32	2.26	2.14
7	U100	314.87	302.69	3.15	3.06
7	U100	314.87	302.69	3.15	3.06
7	U100	314.87	302.68	3.15	3.06
13	U197	749.77	848.68	5.88	6.07
13	U197	749.77	848.69	5.88	6.07
13	U197	749.77	848.68	5.88	6.07
15	U12	41.47	45.24	3.76	3.77
15	U12	41.47	45.24	3.76	3.77
15	U12	41.47	45.24	3.76	3.77
15	U12	41.47	45.24	3.76	3.77
15	U12	41.47	45.24	3.76	3.77
15	U155	582.89	584.34	3.76	3.77
16	U155	763.37	897.15	4.92	5.79
18	U400	1857.6	1976.37	4.64	4.94
21	U400	3783.8	3825.80	9.46	9.56
23	U155	1500.3	1541.02	9.68	9.94
23	U155	150.33	1541.02	9.68	9.94
23	U350	3387.8	3479.72	9.68	9.94
Total	-	18192	18192	-	-

Table V share of each load in total transmission cost and transmission prices for each load, first method

Bus No	*Bus demand*	*LS ($) DC*	*LS ($) AC*	*LTP ($/MW-h) DC*	*LTP ($/MW-h) AC*
1	108.00	0.00	0.00	-	-
2	97.01	15.86	1.69	0.16	0.02
3	180.01	2312.8	2277.7	12.85	12.65
4	74.01	835.56	925.99	11.29	12.51
5	71.01	544.79	634.81	7.67	8.94
6	136.01	1746.4	1870.3	12.84	13.75
7	125.01	0.00	0.00	-	-
8	171.01	928.15	1007.8	5.43	5.89
9	175.01	2038.4	2139.3	11.65	12.22
10	195.01	2274.2	2391.5	11.66	12.26
13	265.01	391.88	336.03	1.48	1.27
14	194.01	2133.3	2271.4	11.00	11.71
15	317.02	929.74	921.73	2.93	2.91
16	100.01	599.67	655.05	6.00	6.55
18	333.01	287.32	293.87	0.86	0.88
19	181.01	1814.8	1822.1	10.03	10.07
20	128.01	640.00	642.61	5.00	5.02
Total	2850	18192	18192	-	-

The results of active power transmission cost allocation are presented in Tables IV and V for generating units and loads respectively. As can be seen in Table III, the results of DC and AC optimal power flow sub-routines differ in many respects, so to make the comparison easier, a transmission price is defined, for each unit/load as the ratio of its share in $ to its generation/consumption in MW-h. In order to validate the results, the problem is solved using method of [9] for this case (but the results are not included here) and the results were completely same for DC load flow. In the case of using AC load flow, there are some little differences in the results due to different ways of dealing with the loss issue.

There are some interesting points in the results of these two tables. Transmission cost is split into two same shares between units and loads. The share of load at bus 1 is zero even though the consumption is not zero, because there is no line connected to this bus which delivers active power.

2) *Peak load, second method*

As mentioned earlier in sub-section III. B circuit lows and active and reactive bus power balance equations can be used to solve the power flow tracing problem. This method is applied here and the results of active power transmission cost allocation are presented in Tables VI and VII for generating units and loads respectively. Comparing the results with those of Tables IV and V, one can deduce that though proportional sharing has some advantages (e.g. modeling simplicity and being explainable), it is not fair enough especially for a deregulated system where the payoffs should be calculated based on the real usage of participants. The results of this method are near to the results of the first method but there are some differences that cannot be neglected. Tables VI and VII in contrast with IV and V show that the value of reactive power which a unit generates or a load consumes affects the share of this unit/load in flow of each line. It is noticeable that the price of transmission is no longer equal for units 2 and 3, due to replacing proportional sharing assumption with circuit lows.

Table VI share of each unit in total transmission cost and transmission prices for each unit, second method

Bus No	*Unit type*	*US ($) AC*	*UTP ($/MW-h) AC*
1	U20	0.00	-
1	U20	28.67	1.79
1	U76	141.12	1.86
1	U76	141.12	1.86
2	U20	34.39	2.15
2	U20	0.00	-
2	U76	165.21	2.17
2	U76	165.21	2.17
7	U100	275.69	3.01
7	U100	275.69	3.01
7	U100	275.69	3.01
13	U197	1102.8	6.70
13	U197	1102.8	6.70
13	U197	1102.8	6.70
15	U12	5.25	2.62
15	U12	5.25	2.62
15	U12	5.25	2.62
15	U12	5.25	2.62
15	U12	5.25	2.62
15	U155	402.87	2.60
16	U155	1988.2	12.83
18	U400	1351.0	3.38
21	U400	3524.9	8.81
23	U155	1437.8	9.28
23	U155	1437.8	9.28
23	U350	3212.0	9.18
Total	-	18192	-

Table VII share of each load in total transmission cost and transmission prices for each load, second method

Bus No	*Bus demand*	*LS ($) AC*	*LTP ($/MW-h) AC*
1	108.00	0.00	-
2	97.01	1.71	0.02
3	180.01	2551.1	14.17
4	74.01	885.09	11.96
5	71.01	715.22	10.07
6	136.01	1587.7	11.67
7	125.01	0.00	-
8	171.01	1082.5	6.34
9	175.01	1967.8	11.24
10	195.01	2183.3	11.20
13	265.01	293.66	1.11
14	194.01	2259.6	11.65
15	317.02	1718.5	5.42
16	100.01	653.19	6.53
18	333.01	316.94	0.95
19	181.01	1505.5	8.32
20	128.01	470.18	3.67
Total	2850	18192	-

V. Conclusion

The results of case studies show both methods can effectively solve the active and reactive power flow tracing problems. The first method which assume proportional sharing to find the participants' shares in power flow of each line gives same results as previous methods in this category for DC power flow modeling, but the its results are slightly different when an AC power flow is used to model the network operation, because of different method of handling the loss issues. The results of second method which uses circuit lows are different from the results of first method to show that the reactive power flow affects the share of each unit and each load in power flow of each line, especially in a system with highly inductive loads.

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1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

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

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

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.
- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

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

Materials:

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

Methods:

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

Approach:

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

What to keep away from

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

Results:

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

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.

You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

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

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
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- Do not present the similar data more than once.
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- Never confuse figures with tables - there is a difference.

Approach

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

Figures and tables

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

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- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.

- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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