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Contents

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Journal of Energy and Management

Vol 1 No 1

EDITORIAL

We are happy to bring you the first issue of the much awaited research journal, Journal of Energy and Management.

This issue of the journal has papers representing energy technology and energy management. Prof. Arshdeep Bahga, et al., Georgia Institute of Technology, Atlanta, USA, explored important factors affecting permeability of Tight Gas Sandstones reservoirs. The authors proposed two approaches for prediction of permeability in in-situ conditions. The proposed approaches capture the key parameters that affect permeability in reservoir conditions, such as, microstructure (which is characterized by parameters such as porosity, pore throat diameter and grain size), diagenetic processes (which is characterized by the degree of cementation), bedding architecture (which is characterized by primary sedimentary structure) and in-situ conditions (such as saturation and confining pressure). Further, two empirical models have been proposed based on multivariate regression analysis and artificial neural networks. Validation of the approach has been made using tight gas sandstone data from six western US basins.

In the second article of the Journal, Naitik Trivedi et al., discussed the effect of dynamic loading on different types of distance relays characteristics and the relay load ability limits at a different power factor angle. The paper emphasised that modern distance relays are designed with different characteristics in order to demonstrate that they can provide better protection and at the same time results in significant improvement of the performance of distance relays during wide area disturbances by preventing the operation of distance relays under dynamic load conditions. However, blocking the operation of the distance elements if a fault occurs at this time may result in a further degradation of the system conditions. The study used simulation and the results shows the impact of different MTA on a relay load ability limit. The comparison of MHO characteristics and lens characteristics are carried out in PSCAD/EMTDC software. The network used in this paper is 230 kV, 300 km radial Transmission line systems.

The journal has interesting studies on energy management side too. The third article by Professor Siddharth Varma has analysed the Indian petroleum industry by applying Porter's Five Forces Model. The paper can help the reader to understand the competitive environment of the Indian petroleum industry and its implications on supply chain performance. As compared to discrete manufacturing supply chains, process industry supply chains are relatively less researched. Though Porter's Five Forces Model is an old concept its application to the petroleum industry especially with reference to India is new. The insights provided by this paper could be valuable to industry as well as policy makers.

In the fourth paper, Amandeep Kaur and Amandeep Singh Rattol studied commodity hedging through zero-cost collar and its financial impact. Focusing on the popularity of option derivatives and hedging and risk management, the authors studied the zero cost collar option contracts for commodity hedging and its fair valuation and accounting. The paper underlines the main advances in hedge accounting proposed by IASB & IFRS 9 and tests the effectiveness of zero cost collar option strategy on NYMEX WTI crude oil in the backdrop of falling commodity prices. While the study result can have a great significance from an economic viewpoint, they may also be utilized for hedge accounting purposes & accounting for time value of zero cost collar strategy.

The last article of the journal focused on Islamic State of Iraq and Syria (ISIS) and its implications on energy security. In this paper, Dr. Sanjay kumar Pradhan has anyalsed the mechanisms through which ISIS carries out its oil market, ISIS and its adverse impact on energy market and infrastructure in Iraq and Syria, implications of energy market, intricacies or nexus in black market, outcomes of armed operation by external powers such as Russia and coalition forces with specific reference to United States. While agreeing that eliminating ISIS and restoring oil market stable in Syria and Iraq is a challenging task to all the stake holders of war, the author opined that to make the operations a successful one suggested steps includes keeping the ISIS deprived from getting oil fields, starve it of revenues and block it from the maritime connectivity; Turkey and Syria are also required to show their sincere commitment to stop oil black marketing across their border regions; United States should put pressure on its coalition partners in the Middle East to take tough measures against oil black marketing with the ISIS. Implementing the United Nations Security Council resolution related to trade in oil and refined oil products, modular refineries, and related materials etc would be another important step.

The journal also feature a Book review by Mr. Saumyaranjan Sahoo. Mr. Sahoo has reviewed a book titled '*Achieving Universal Energy Access in India: Challenges and the Way Forward*', authored by P.C. Maithani, and Deepak Gupta (Sage Publications India Pvt. Ltd). The book takes a critical look at the present energy policy and addresses ways to improve energy penetration. In doing so it encourages the use of renewable energy as an alternate medium, challenging the traditional power proponents.
With best wishes to all of you.

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IN-SITU PERMEABILITY PREDICTION APPROACH FOR TIGHT GAS SANDSTONE RESERVOIRS

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KEYWORDS

Tight gas sandstones, permeability prediction, reservoir quality, diagenesis

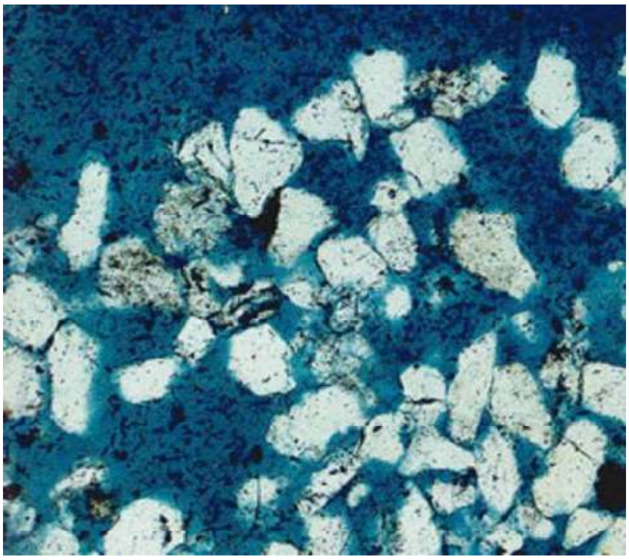
Abstract: In this paper we describe the important factors affecting the permeability of Tight Gas Sandstones reservoirs. We propose two approaches for prediction of permeability in in-situ conditions. The proposed approaches capture the key parameters that affect permeability in reservoir conditions, such as, microstructure (which is characterized by parameters such as porosity, pore throat diameter and grain size), diagenetic processes (which is characterized by the degree of cementation), bedding architecture (which is characterized by primary sedimentary structure) and in-situ conditions (such as saturation and confining pressure). We propose two empirical models based on multivariate regression analysis and artificial neural networks. To validate the proposed approach we have used tight gas sandstone data from six western US basins

1. INTRODUCTION

The term "Tight Gas Reservoir" has been coined for reservoirs of natural gas with an average permeability of less than 0.1 mD and porosity less than 10%, Law & Curtis (2001). There could be a number of reasons for making a reservoir tight. Basically the permeability that determines the ease at which a fluid can flow, is a multivariate function governed by the Darcy's law of fluid flow in porous media. Effective porosity, viscosity, fluid saturation and the capillary pressure are some of the important parameters which control the effective permeability of a reservoir, Campbell (2009), Naik (2002), Misra (2008).

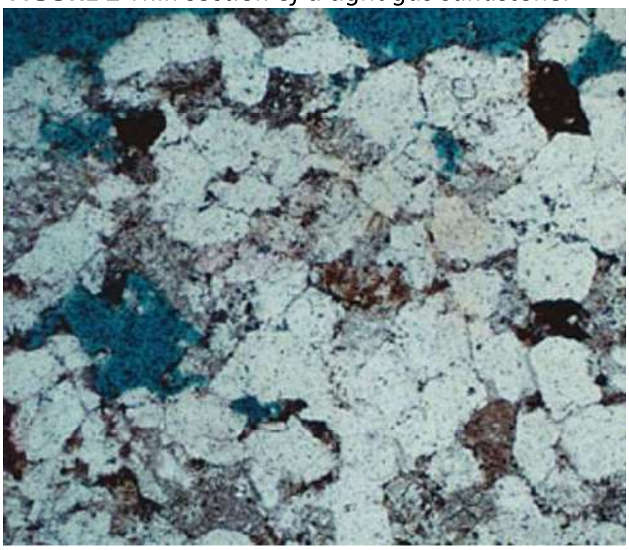
Figures 1 and 2 show the thin sections of conventional and tight gas sandstones respectively. In tight gas sandstones, the pores are poorly connected by very narrow capillaries resulting in very low interconnected porosity and hence very low permeability. Gas flows through these rocks generally at low rates and special methods are necessary to produce this gas.

Figure 1 *Thin section of a conventional sandstone*



The pore space (blue areas) can be seen to be interconnected so gas is able to flow easily from the rock, (Naik, 2002).

FIGURE 2 *Thin section of a tight gas sandstone.*



The pores (blue areas) are irregularly distributed and the porosity of the rock can be seen to be much less than the conventional reservoir (Naik, 2002).

Reservoir quality is determined by the ability for storage and deliverability of fluids contained in the pores of the rocks in a reservoir. Permeability is the key parameter that determines the quality of a reservoir. In addition to permeability, the reservoir quality also depends on parameters such as porosity, diagenetic processes, distribution of natural fractures, etc. Quantifying the quality of a tight gas reservoir involves (1) understanding the relationships between the properties such porosity, pore throat radius, saturation, confining pressure, etc., (2) the architecture of the distribution of these properties, and (3) predicting the effective gas permeability at reservoir conditions.

Of all the properties affecting reservoir quality, permeability is the most important and most difficult property to determine and predict. To quantify the reservoir quality we need to predict the in-situ permeability. Previous studies have shown that permeability predicted in routine air conditions is greater than the permeability under reservoir conditions, often by more than a hundred-fold, because of the absence of water saturation, and relief of confining pressure. In tight gas sandstones, routine air permeability values typically range from 10 to 1,000 times greater than in-situ gas and liquid permeability values, Miller et al. (2007).

The major contributions of this paper are, (1) propose a core sample based approach for prediction of in-situ permeability for tight gas sandstone reservoirs, (2) propose a hybrid approach that uses both wireline logs and core sample measurements to predict in-situ permeability, (3) propose empirical prediction models based on multivariate regression analysis (MVA) and artificial neural networks (ANNs), and (4) validate the proposed approaches with data from Mesaverde tight gas sandstones of western US basins, KGS (2009).

Section II describes three broad categories of permeability prediction approaches. In section III we describe the commonly used permeability prediction models and classify them into one of the broad categories described in section II. Section IV provides details of our proposed approaches for in-situ permeability prediction. Section V describes the important parameters that affect permeability and how the proposed approaches capture these parameters. Section VI provides details on the two permeability prediction models used in our proposed approaches. We propose empirical models based on multivariate regression analysis (MVR) and artificial neural networks (ANN). Section VII provides results of permeability prediction using the proposed approaches.

2. PERMEABILITY PREDICTION APPROACHES

The permeability prediction approaches can be classified into three broad categories:

2.1. Wireline logs based approach

Wireline logs are obtained by means of measuring equipment (logging tools) lowered on cable (wireline) into the well. Measurements are transmitted up the cable to a surface laboratory or computer unit. A large number of different logs may be run, each recording a different property of the rocks penetrated by the well. Wireline logs allow in situ measurements of parameters related to porosity, lithology, hydrocarbons, and other rock properties. These logs provide a consistent one dimensional profile of rock properties. However, in the wireline log based approach the measured properties may not be of direct interest and not uniquely related to the properties that are of direct interest (such as permeability, porosity, etc.). Wireline logs allow a megascopic (that relates to the scale of grid blocks) analysis. A number of previous studies have proposed empirical models which capture relationships between permeability and variables from wireline logs, Ahmed (1991), Coats (1974), Mohaghegh (1997).

Figure 3 shows the typical approach for permeability prediction using wireline logs. The approach begins with computing the volume of shale from Gamma Ray logs. The total porosity is determined from Neutron and Density logs. The effective porosity is determined from total porosity after correcting for the volume of shale. Water saturation is determined from formation water resistivity using Archie equation. Bulk Volume Water (BVW) is computed from effective porosity and water saturation Bulk Volume Water Irreducible (BVI) is computed using depth plots where BVV is approximately constant. Irreducible Water Saturation (Swi) is computed from total porosity and bulk volume water irreducible (BVI). Finally, permeability estimated using Timur equation Timur (1968).

2.2. Core sample analysis based approach

Core samples obtained while drilling (using a core-barrel), by virtue of their size and continuous nature, permit a thorough geological analysis over a chosen interval. Measurements on core samples are done in routine air or simulated in-situ conditions. Using core samples it is possible to measure properties of direct interest (such as permeability, porosity, etc.) and develop prediction models using the measured properties. However, core samples are extracted from discrete points in the reservoirs, therefore do not provide a continuous profile like wireline logs. Core samples allow microscopic (that relates to pore and grain sizes) and macroscopic (that relates to core-plug scale) analysis. A limited number of laboratory test data on core samples can be correlated with geophysical log measurements at specific depths. Data from the wireline logs can then be used for predictions in un-core regions. A number of previous studies have determined empirical relationships between permeability and other properties such as porosity, pore throat radius, grain size, etc., which are measured from core samples Glover (2006), Pittman (1992).

2.3. Hybrid approach

Hybrid approaches use both core sample and wireline log measurements to predict in-situ permeability. Schlumberger (2011), has described one such hybrid approach where the facies identified from the wireline logs define “containers” that are populated with multiple, equally well-constrained core-measured properties. In uncored wells these facies are recognized through logs alone and their inferred core-equivalent properties are extracted from the associated containers.

***FIGURE 3** A typical approach for permeability prediction using wireline logs*

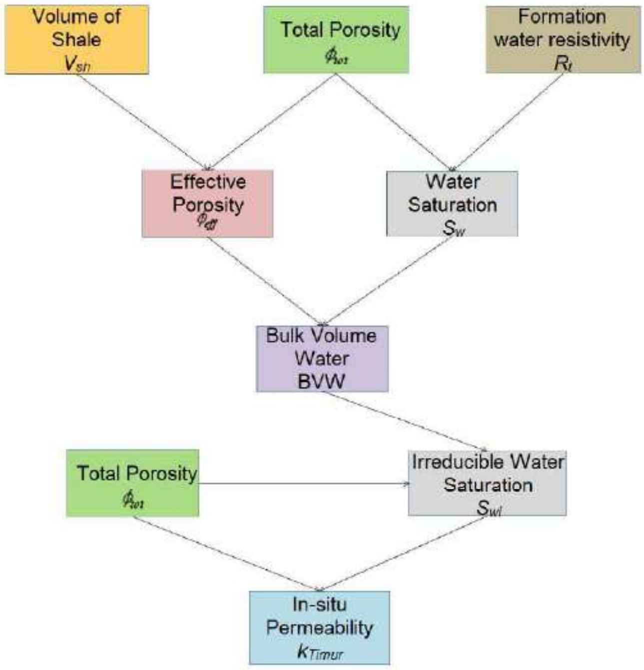
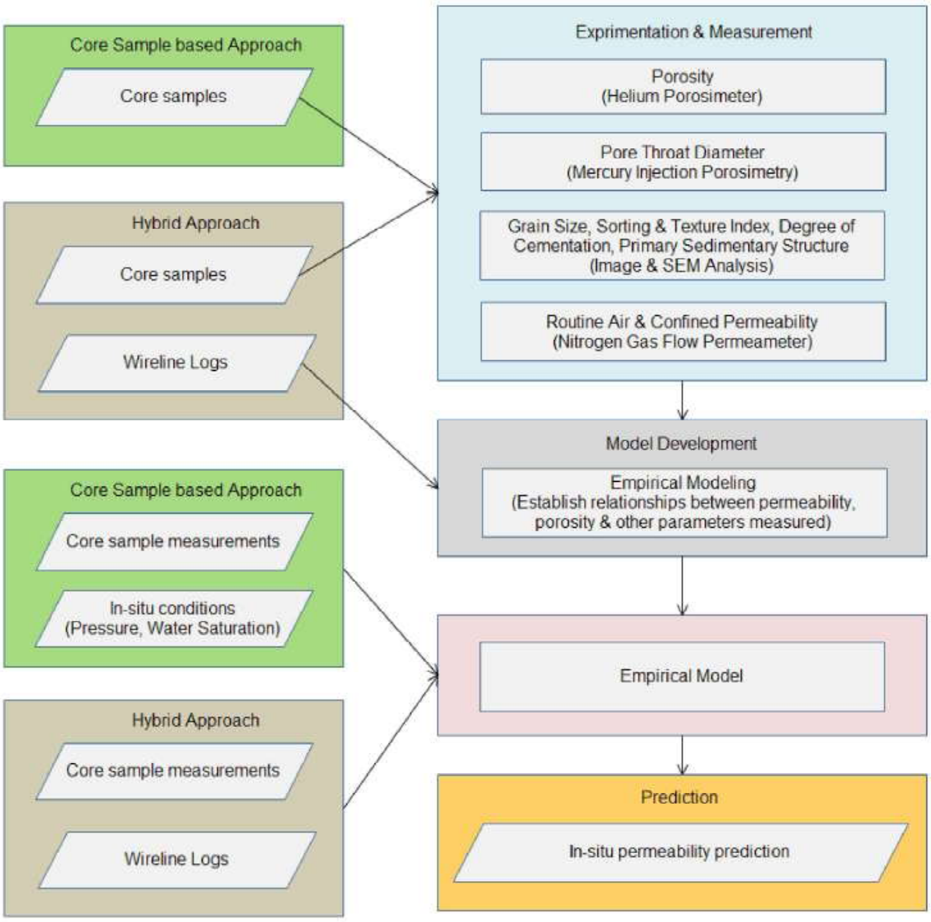


***FIGURE 4.** Proposed approaches for in-situ permeability prediction.*



We propose two approaches one based on core samples and the other which is a hybrid approach that uses both core samples and wireline logs.

3. COMMONLY USED PERMEABILITY PREDICTION MODELS

We now describe some commonly used models for permeability prediction. The Kozeny-Carman model is based on work of Kozeny which was later reworked by Carman. The most popular form of the model is given by,

$$k = \frac{1}{2S_{gr}^2}\frac{\phi^3}{(1-\phi)^2}$$

where k is permeability in m^2, φ is porosity in fraction and Sgr is the specific surface area per unit bulk volume. Specific surface area is the total area exposed within the pore space per unit grain volume. A more general form of Kozeny-Carman equation is,

$$k = \frac{A\phi^3}{S_{gr}^2}$$

where A is an empirical constant ("the Kozeny constant"). Since Sgr is not directly measurable, therefore irreducible water saturation is used as a proxy for Sgr, leading to empirical equations such as Timur equation. Kozeny-Carman model is used in core sample based approach. Approximations such as Sgr = 6 / dg where dg is the grain size have been used for spherical grains which allows Kozeny-Carman model to be used for permeability prediction with core sample analysis data, Glover (2006) et al.

Timur (1968) developed an empirical model which is given by,

$$k = \frac{0.136\phi^{4.4}}{S_{wi}^2}$$

where φ is porosity and Swi is irreducible water saturation. The Timur model is commonly used for permeability prediction using wireline logs as shown in figure 3.

Coates et al. (1991) has provided an equation to calculate permeability from NMR logs, which is given by,

$$k = (10\phi)^4\left(\frac{FFI}{BVI}\right)^2$$

where the ratio (FFI/BVI) is based on a T2 cut-off dividing the NMR spectra into a bound fluid (BVI) and a free fluid (FFI) region. Free Fluid Index (FFI) is the product of hydrocarbon saturation and porosity, FFI = φ(1 − Swi). Bulk Volume Water Irreducible (BVI) is estimated as, BVI = φ Swi. The ratio (FFI/BVI) serves as a proxy for specific surface area Sgr.

A newer model called RGPZ is described by Glover et al. (2006). This is an analytically derived model as opposed the other models discussed in this section. The RGPZ model is given by,

$$k = \frac{d^2\phi^{3m}}{4am^2}$$

where k is permeability in m2, d is grain size, φ is porosity, m is cementation exponent, and a is a constant which is typically set to 8/3 for quasi-spherical grains. Glover et al. (2006) have described a core sample based permeability prediction approach using the RGPZ model.

4. PROPOSED APPROACHES FOR IN-SITU PERMEABILITY PREDICTION

Figure 4 shows the proposed approaches for in-situ permeability prediction. We propose two approaches, one based on core samples and the other which is a hybrid approach that uses both core samples and wireline logs. The proposed approaches are generic in nature and can be applied to different reservoirs. It is important to note that the empirical relationships established for one reservoir may not be transferable to another. Therefore generic modelling approaches that use core sample analysis data, wireline log data or both, to first establish the prediction models and then predict permeability can provide more accurate results.

4.1. Proposed core sample based approach

In core sample (CS) based approach, measurements on the core samples are done for properties such as porosity (using Helium porosimeter), pore throat diameter (using Mercury Injection Capillary Pressure experiment), the three indices called grain size, sorting & texture index, degree of cementation and primary sedimentary structure (using thin section image analysis and SEM analysis), routine air and confined permeability (using Nitrogen gas flow permeameter). The data from these measurements is then used to develop empirical models based on multivariate regression analysis (CS-MVR) and artificial neural networks (CS-ANN) that capture the relationships between the permeability, porosity and other parameters that affect permeability.

Figure 5 shows the block diagram of the proposed core sample based approach for in-situ permeability prediction. This is a two-step approach in which first the routine air permeability is predicted using parameters such as porosity, pore throat diameter, and three indices called the grain size, sorting & texture index, degree of cementation and primary sedimentary structure, which are obtained from core sample measurements. In the second step we incorporate in-situ conditions to predict the permeability in reservoir conditions. The advantage of this proposed core sample based approach is that it is able to capture complex relationships between permeability and other parameters which are reservoir specific, as opposed to empirical models such as Timur which may not provide accurate predictions for all reservoirs.

Moreover, a limitation of Timur and Coates models is that they are highly sensitive to very small changes in porosity which is magnified by large porosity exponents. Therefore these models show a greater spread in the predicted values as compared to the predictions from our proposed models. Furthermore, Timur, Coates and RGPZ models all use a single mathematical relationship (i.e. with the same porosity exponent) for a large range of porosities.

However, previous studies for tight gas sandstones have shown that separate relationships for different classes of porosities (low, medium and high) can provide more accurate predictions, Bourbie et al. (1985). In our proposed approach, indices such as grain size, sorting & texture index and degree of cementation capture the different classes of porosity.

4.2. Proposed hybrid approach

In the hybrid approach (HY) we use the core sample measurements and wireline log data for developing the empirical models and permeability prediction using the developed models as shown in figure 4.

This approach allow in-situ permeability predictions in uncored regions. Figure 6 shows the block diagram of the proposed hybrid approach for in-situ permeability prediction. This approach uses both wireline logs and core samples. Each of the facies derived from the wireline logs represent a “container” as in the Schlumberger Tight Rock Analysis approach.

A number of core samples are extracted from each container. In the proposed hybrid approach properties measured from the core samples such as grain size, sorting & texture index, degree of cementation and primary sedimentary structure, are extrapolated to the entire container. Wireline logs provide measurements of irreducible water saturation and in-situ porosity. In-situ permeability is then predicted by the proposed prediction models based on multivariate regression analysis (HY-MVR) and artificial neural networks (HY-ANN), which use the core derived and wireline log derived properties. With the hybrid approach it is possible to provide a continuous prediction profile at reservoir conditions.

Figure 5. Block diagram of the proposed core sample (CS) based approach for in-situ permeability prediction. This is a two-step approach in which first the routine air permeability is predicted using proposed empirical models (CS-MVR, CS-ANN) and then the in-situ effects are added to predict the in-situ permeability.

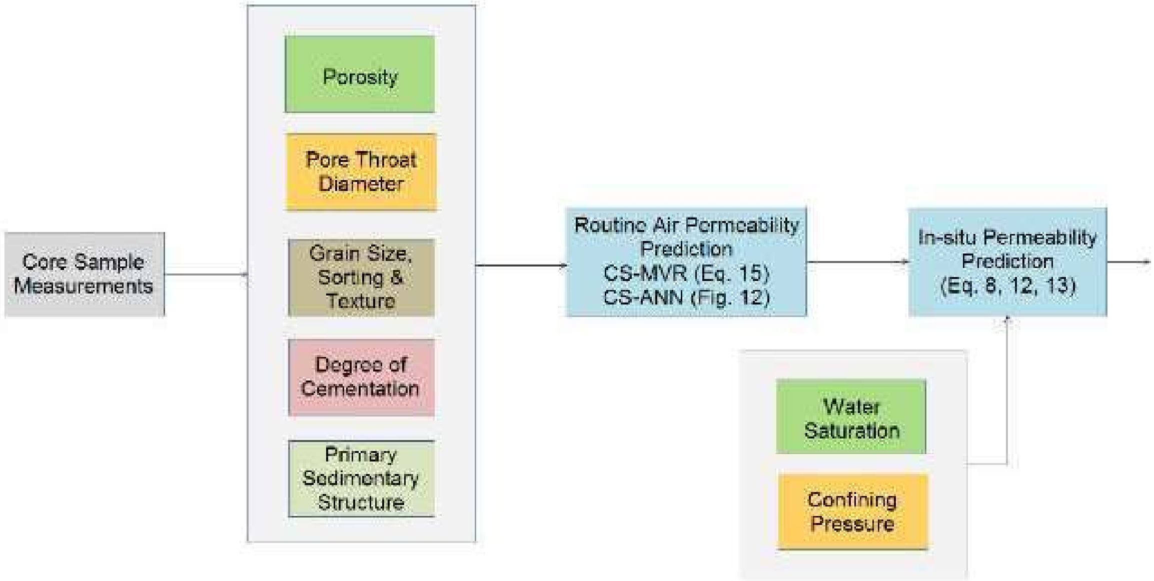
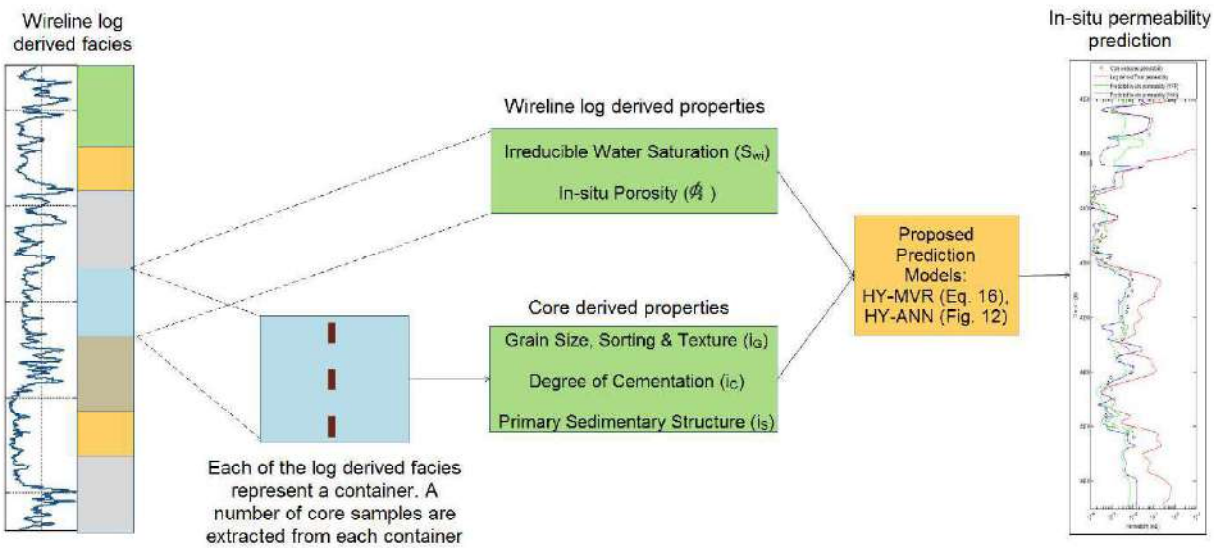


***FIGURE 6.** Block diagram of the proposed hybrid approach (HY) for in-situ permeability prediction**



**Each of the facies derived from the wireline logs represent a container. A number of core samples are extracted from the containers. The properties measured from the core samples are extrapolated to the entire container. In-situ permeability is predicted by the proposed prediction models (HY-MVR, HY-ANN) which use the core derived and wireline log derived properties.*

5. FACTORS AFFECTING PERMEABILITY

In this section we discuss the important factors that affect permeability and how proposed approaches are described in section IV capture these parameters. Permeability depends on, microstructure (which is characterized by parameters such as porosity, pore throat radius and grain size), diagenetic processes (which is characterized by the degree of cementation), bedding architecture (which is characterized by primary sedimentary structure) and in-situ conditions (such as saturation and confining pressure).

5.2. Effect of microstructure on permeability

Microstructure of a rock is characterized by porosity, pore throat radius and grain size.

5.2.1. Porosity

Porosity is defined as the fraction of the total volume of a rock that is not occupied by the solid constituents. The total porosity, φT, which consists of all the void spaces (pores, channels, fissures, vugs) between the solid components, is expressed as,

$$\phi_T = \frac{V_t - V_s}{V_t} = \frac{V_p}{V_t}$$

where Vp = volume of all the empty spaces (which is generally occupied by oil, gas or water), Vs = volume of the solid materials and Vt = total volume of the rock.

We distinguish two components in the total porosity, φT = φCP + φEX. Closed packed porosity, φCP, is the primary porosity which is intergranular or intercrystalline. It depends on the shape, size and arrangement of the solids, and is the type of porosity encountered in clastic rocks. Expanded porosity, φEX, is the secondary porosity, made up of vugs caused by dissolution of the matrix, and fissures or cracks caused by mechanical forces, Prince et al. (1999), Serra (1984). Closed packed porosity exists due to the pore features that have scales less than grain size is associated with pore/grain shape. Whereas, expanded porosity exists due to the pore features that have scales greater than grain size and is associated with the interrelationship of grains, grain packing and micro-fractures.Interconnected porosity, φIC, is made up only of those spaces which are in communication. This may be considerably less than the total porosity, φT. The part of the interconnected porosity in which the diameters of the connecting channels are large enough to permit fluid flow is called potential porosity, φP.

A permeable rock must have connected porosity. The permeability of a rock is a measure of the ease with which fluid of a certain viscosity can flow through it, under a pressure gradient. The absolute permeability k describes the flow of a homogeneous fluid, having no chemical interaction with the rock through which it is flowing.

5.2.2. Grain Size

Grain size defines the minimum center-to-center distance at which grains can pack together and thus defines the fundamental spatial density of porosity (pore-to-pore separation). Pore features that exist at scales less than grain size are associated with pore/grain shape, while those that exist at scales greater than grain size are associated with the interrelationship of grains, i.e grain sorting and texture Prince et al. (1999). The shape and size of the grains and their degree of sorting affect the pore size and hence the porosity and permeability.
Study of the microstructure of a rock can be done by scanning electron microscope photography. Analysis of the images of the microstructure allows relating the porosity with pore sizes and grain size.
In our proposed approach we capture the grain size, sorting and texture in the form of an index as shown in Table 1. Using thin section image analysis we classify the cores samples into 10 different classes shown in Table 1.

TABLE 1: Grain size, sorting & texture index

Index	Description
0	Shales
1	Silty shales (60-90% clay)
2	Siltstones or very shaly sandstones (40-65% clay and silt)
3	Moderately shaly sandstones (10-40% clay and silt)
4	Sandstones, very fine
5	Sandstones, fine
6	Sandstones, medium
7	Sandstones, coarse
8	Sandstones, very coarse to gravely sandstone
9	Conglomerate, matrix or clast supported

Source: Cluff et al. (1994), Byrnes et al. (2008)

5.2.3. Pore throat radius

Pore throat radii determine the amount of connectivity of the pores, i.e. the interconnected porosity, φIC, and hence the permeability. It is possible to have a very high porosity without any permeability at all, as in the case of pumice-stone (where there is no interconnecting pore throats) and clays and shales (where the pore throats are so fine that the surface tension forces are strong enough to prevent fluid movement), Serra (1984). The controlling factor, therefore, is not the porosity itself, but the radii of the connecting channels.

The distribution of pore throat radii can be determined using Mercury Injection Porosimetry. Washburn equation expresses the relationship between the pore throat, throat radius and capillary pressure as,

$$r = -\frac{2Y cos\theta}{P_\theta}$$

where, r is the pore throat radius, Y is the mercury surface tension, θ is the contact angle and P is the capillary pressure. Mercury Injection Porosimetry involves injecting mercury at increasing pressure into a sample, which has been previously evacuated. Capillary pressure-saturation curves are generated by recording mercury pressures and saturations. Pore throat radii are calculated at certain mercury saturations using the Washburn equation.
In our proposed approach we use the pore throat diameter (d50) determined at 50% mercury saturation.

5.3. Effect of diagenetic processes on permeability

Diagenesis is the process by which the underlying rock goes through changes at low temperatures and pressures due to physical and chemical processes. Physical processes are compaction and stress that act on the rock and the sub-surface fractures. These chemical diagenetic mechanisms are cementation and mineral bridge formation. Cementation is the process by which carbonates and quartz based cement is deposited in the matrix of the rock.

Figure 7 shows the effects of diagenesis in tight gas sandstones. The pore spaces have been filled by a special resin that makes them appear blue and can easily be identified. Notice the fine clay minerals (illite), grown on the pore surfaces during diagenesis. Clay minerals are most likely the main cause for pore throat clogging during hydraulic fracturing treatments, Naik (2002).

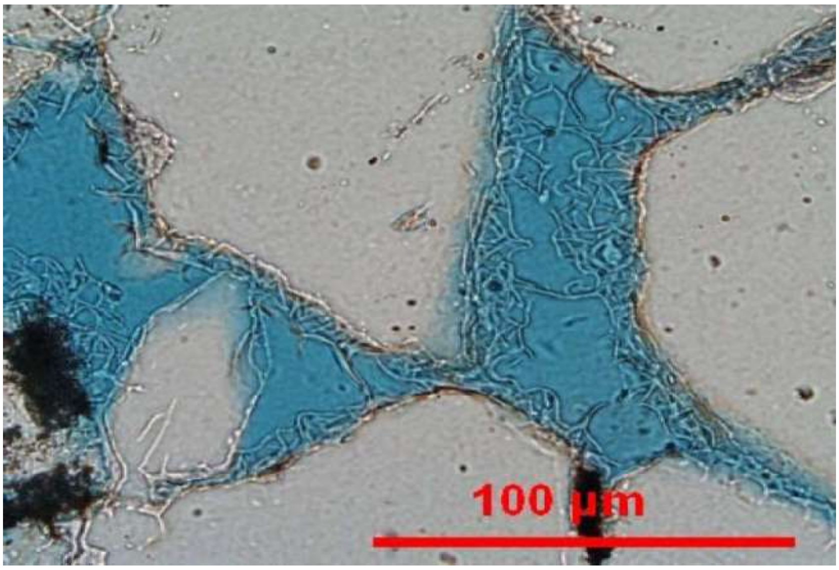
In our proposed approach we use an index called Degree of cementation to capture the diagenetic effects. Degree of cementation is estimated using thin section image analysis, which classifies the images into 10 classes as shown in Table 2.

TABLE 2: Degree of cementation

Index	Description
0	Totally cemented, dense, hard, unfractured
1	Dense, fractured
2	Well indurated, mod-low porosity (3-10%), unfractured
3	Well indurated, mod-low porosity (3-10%), fractured
4	Well indurated, mod-low porosity (3-10%), highly fractured
5	Indurated, mod-high porosity (>10%), unfractured
6	Indurated, mod-high porosity (>10%), fractured
7	Indurated, mod-high porosity (>10%), highly fractured
8	Poorly indurated, high-v. high porosity, soft
9	Unconsolidated sediment

Source: Cluff et al. (1994), Byrnes et al. (2008)

***FIGURE 7** Thin section of a tight gas sandstone showing diagenesis effects.*



Source: Naik (2002)

TABLE 3: Primary sedimentary structure

Index	Description
0	Vertical perm barriers, shale dikes, cemented vertical fractures
1	Churned/bioturbated to burrow mottled (small scale)
2	Convolute, slumped, large burrow mottled bedding (large scale)
3	Lenticular bedded, discontinuous sand/silt lenses
4	Wavy bedded, continuous sand/silt and mud layers
5	Flaser bedded, discontinuous mud layers
6	Small scale (< 4 cm) x-laminated, ripple x-lam, small scale hummocky x-bd
7	Large scale (> 4 cm) trough or planar x-bedded
8	Planar laminated or very low angle x-beds, large scale hummocky x-bd
9	Massive, structureless

Source: Cluff et al. (1994), Byrnes et al. (2008)

5.4. Effect of bedding architecture on permeability

The effect of bedding architectures is captured by an index called primary sedimentary structure which is shown in Table 3.

5.5. Effect of in-situ conditions on permeability

5.5.1. Saturation

In the majority of sediments, initially impregnated with water, gas can only penetrate the water-filled pore-space under a driving force superior to the capillary pressure at the gas-water interface. In other words, in formations possessing very fine capillaries, where capillary forces are high, a very high driving pressure would be required to cause the gas to displace the water. Under ordinary conditions, such formations would be impermeable to gas. Thus the concept of permeability is a relative one, i.e. the same rock being permeable to water, is impermeable to gas at a certain pressure, but permeable to both water and gas if one of them is submitted to a force greater than the capillary forces acting.

Darcy's law assumes a single fluid. However, a reservoir can quite well contain two or even three fluids (water, oil and gas). In such cases, we must consider diphasic flow and relative permeability. The flows of the individual fluids interfere and their effective permeabilities are less than absolute permeability k defined in Darcy's equation.

The effective permeability describes the passage of a fluid through a rock, in the presence of other pore fluids. It depends not only on the rock itself, but on the percentages of fluids present in the pores, i.e., their saturations.

The relative permeabilities (krw, krg) are simply the ratios of the effective permeabilities (kw,kg) to the absolute (singe-fluid) permeability, k.

They vary between 0 and 1, and can also be expressed as percentages : krw = kw / k for water, krg = kg / k for gas. As the water saturation increases, the relative permeability of gas, krg, decreases, while the relative permeability of water, krw, increases.

In our proposed approach we use a modified Corey equation, Byrnes et al. (1979), Corey (1954), to predict krg in low-permeability sandstones,

$$k_{rg} = \left(1 - \frac{(S_w - S_{wc,g})}{(1 - S_{gc} - S_{wc,g})}\right)^p \left(1 - \left(\frac{(S_w - S_{wc,g})}{(1 - S_{wc,g})}\right)^q\right)$$

where Sw is fractional water saturation, Sgc is the fractional critical gas saturation, Swc,g is the fractional critical water saturation relevant to the gas phase, and p and q are exponents expressing pore size distribution influence.

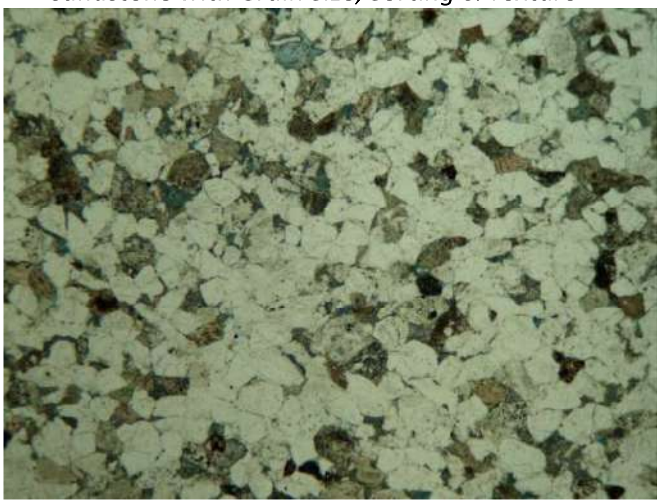
Swc,g and Sgc are estimated using, Byrnes (2003),

$$S_{wc,g} = 0.16 + 0.053 \times \log k_{ik}, (k_{ik} > 0.001mD)$$

$$S_{wc,g} = 0, (k_{ik} < 0.001mD)$$
$$S_{gc} = 0.15 - 0.05 \times \log k_{ik}$$
$$p = 1.7, q = 2$$

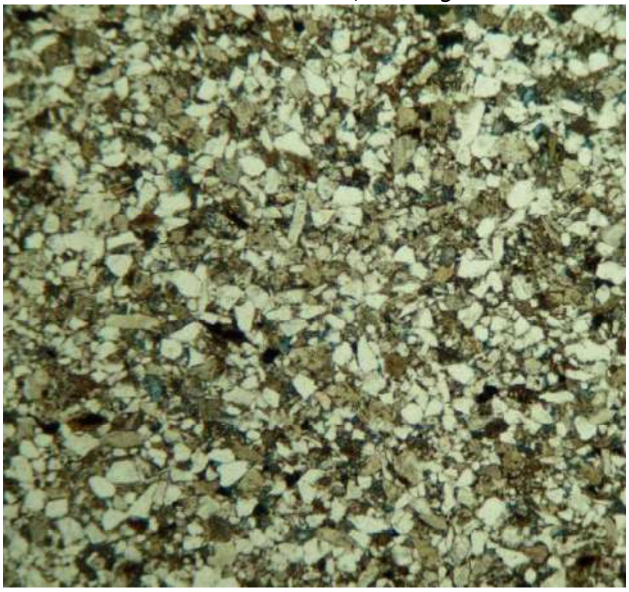
where kik is Klinkenberg absolute-gas permeability measured on a dry sample.

FIGURE 8. *Example of thin section of a tight gas sandstone with Grain Size, Sorting & Texture*



index = 5, Degree of Cementation = 2 and Primary Sedimentary Structure = 8. This image was obtained from a core sample extracted from a depth of 11460.6 ft from "Inexco Wasp A-1'' well of Green River basin, KGS (2009).

FIGURE 9 *Example of thin section of a tight gas sandstone with Grain Size, Sorting & Texture*



index = 4, Degree of Cementation = 2 and Primary Sedimentary Structure = 9. This image was obtained from a core sample extracted from a depth of 11584 ft from "Inexco Wasp A-1'' well of Green River basin, KGS (2009).

5.5.2. Pressure

Due to the effect of in-situ pressure, the pore throat radii decrease which cause a reduction in porosity. There have been extensive studies on the effect of confining pressure on porosity and pore volume compressibility in sandstones, Newman (1973), Somerton et al. (1978). Klinkenberg (1941), characterized the gas slippage, which results from greater gas movement due to decreased molecule-molecule interactions at lower pressure as,

$$k_{gas} = k_{liquid}\left(1+\frac{4CL}{r}\right) = k_{liquid}\left(1+\frac{b}{P}\right)$$

where kgas is gas permeability at pore pressure, kliquid is liquid permeability and is equal to the Klinkenberg permeability kk, c is proportionality constant, L is mean free path of gas molecule at pore pressure, r = pore radius, b is proportionality constant (=f(c, L, r)), and P = pore pressure (atm). Values for b can be estimated from the relation presented by Jones et al. (1980),

$$b = 0.867 k_k^{-0.33}$$

Routine permeabilities of tight gas sandstones are shown to be greater than under reservoir conditions, often by more than a hundred-fold, because of the great relief of stress, absence of connate water, and increased gas slippage.

Permeability decreases with increasing confining stress/pressure. The difference between permeabilities measured at routine conditions (kair) and those measured at confining stress increases progressively with decreasing permeability and increasing confining stress Byrnes et al. (2008), Byrnes (1997).

Jones et al. (1980) modeled the stress dependence of permeability and presented an expression to estimate in-situ permeability from routine permeability as,

$$\log k_i = k / (1 - S\,\mathrm{Log}(P_k / 1000))^3$$

In our proposed approach we characterize the pressure sensitivity of cores using the permeability measured in routine air and confined conditions. From the established relationship between pressure and permeability we can then predict permeability at any given value of pressure. The pressure sensitivity index is given by,

$$\psi = \frac{\log k_{P1} - \log k_{P2}}{\log P1 - \log P2}$$

where kP1 and kP2 are permeabilities measured at net confining pressure of P1 and P2 respectively.

The relationship between permeability and confining pressure is then expressed as,

$$\log k_i = \psi\,\mathrm{Log} P + C$$

6. PROPOSED PERMEABILITY PREDICTION MODELS

As described in section IV, our proposed approaches use data from either the core sample analysis (core sample based approach) or both core samples analysis and wireline logs (hybrid approach) to develop empirical models that capture the relationships between the permeability, porosity and other parameters that affect permeability. In this section we describe the the proposed empirical models.

6.1. Multivariate regression analysis based model

Multivariate regression analysis (MVR) is an approach that allows to determine a formula that captures the relationship between a dependent variable and multiple independent variables.

There is no general mathematical relationship expressing permeability in terms of porosity, pore throat radius and grain size, that can be applied to all cases. There are several published relationships between permeability, porosity and pore throat radius which have been established using empirical studies. Pittman (1992), has determined empirical relationships between permeability, porosity and pore throat radius, using the data from Mercury Injection Porosimetry for sandstone samples. The equation that provides the best estimates of permeability, as pointed by Pittman is,

$$\log k = -1.221 + 1.415 \log \phi + 1.512 \log r_{25}$$

where, k is the air permeability, φ is porosity and r25 is the pore throat radius derived for a mercury saturation of 25%.

For the core sample based approach, we propose an MVR based model (CS-MVR) that establishes empirical relationships of the form,

$$\log k_{air} = A\phi + B \log d_{50} + Ci_G + Di_C + Ei_S + F$$

where kair is routine air permeability, φ is porosity, d50 pore throat diameter determined from MICP experiment at 50% mercury saturation, iG is grain size, sorting and texture index shown in Table I, iC is degree of cementation shown in Table II, iS is primary sedimentary structure shown in Table III.

For the hybrid approach, we propose an MVR based model (HY-MVR) that establishes empirical relationships of the form,

$$\log k_{insitu} = A\phi_{insitu} + BS_{wi} + Ci_G + Di_C + Ei_S + F$$

where kinsitu is in-situ permeability, φincitu is in-situ porosity obtained from wireline logs, Swi is irreducible water saturation obtained from wireline logs, iG, iC and iS are the three indices which are obtained from analysis of core samples in each container which are then extrapolated to the uncored intervals in the containers.

The multiple regression solves for unknown coefficients A, B, C, D, E and F by minimizing the sum of the squares of the deviations of the data from the model (least-squares fit).

6.2. Artificial neural networks based model

The artificial neural network (ANN) based model uses a a two-layer feedforward network, with a sigmoid transfer function in the hidden layer and a linear transfer function in the output layer as shown in figure 12. The hidden layer in the network has 10 neurons. These layers of neurons with nonlinear transfer functions allow the network to learn nonlinear relationships between input and output vectors. Thus the artificial neural network model is able to capture complex relationships between various properties affecting permeability which cannot be captured using simpler algebraic equations.

Rezaee et al. (2006) used an ANN based model to capture relationships between permeability, porosity and pore throat size of carbonate rocks. We propose two different forms of ANN based model. The proposed ANN based model in the core sample based approach (CS-ANN) uses core measured porosity, pore throat diameter, grain size, sorting & texture index (iG), degree of cementation (iC) and primary sedimentary structure (iS) as the input vector. Whereas the proposed ANN based model in the hybrid approach (HY-ANN) uses in-situ porosity and irreducible water saturation which are obtained from wireline logs and the three indices (iG, iC and iS) which are obtained from core samples in each container and then extrapolated to the uncored intervals in the containers.

For training the ANN we divide the data into three subsets. The first subset which is the training set (70 % of data) is used for computing the gradient and updating the network weights and biases. The second subset is the validation set (15 % of data). The error on the validation set is monitored during the training process. The third subset (15 % of data) is used for testing the ANN.

FIGURE 10 *Screenshot of permeability prediction tool that uses the core sample (CS) based approach - routine air permeability prediction.*

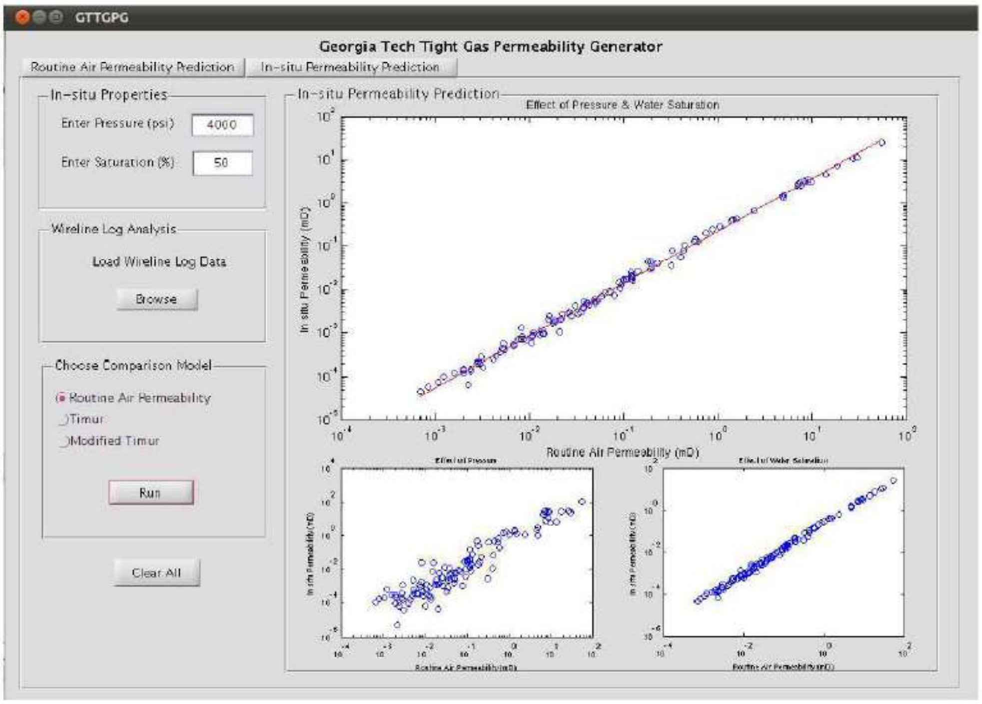


FIGURE 11 *Screenshot of permeability prediction tool that uses the core sample (CS) based approach - in-situ permeability prediction.*

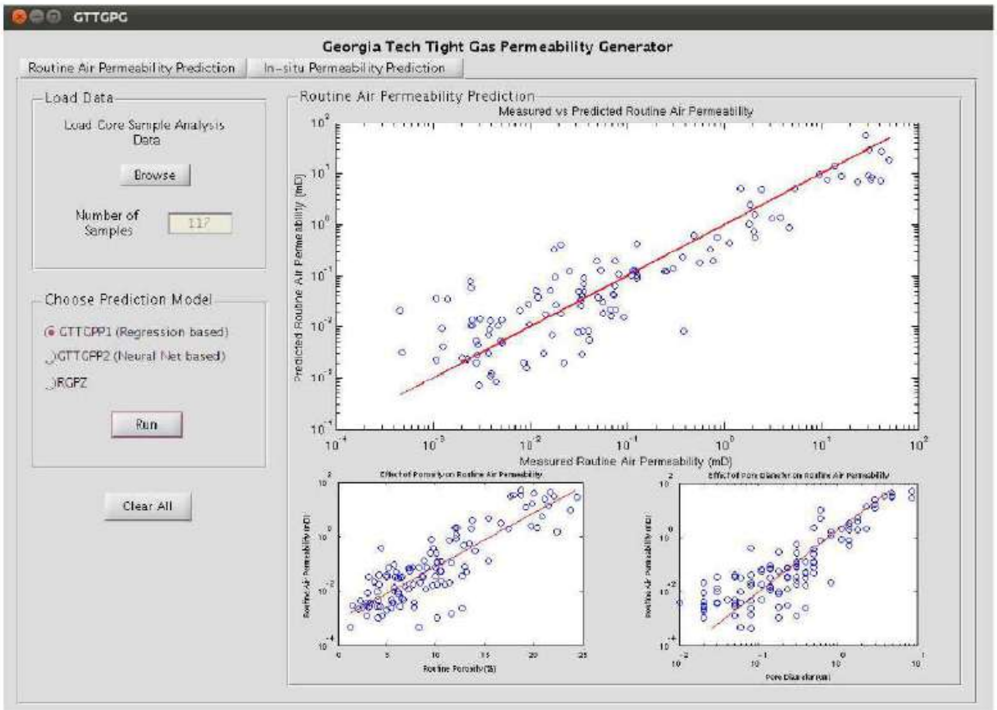
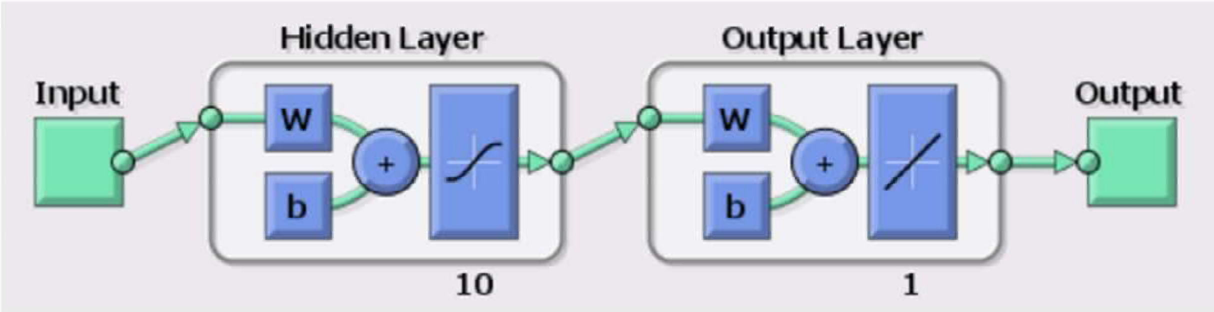


***FIGURE 12** Proposed artificial neural network based model that uses two-layer feedforward network, with a sigmoid transfer function in the hidden layer (with 10 neurons) and a linear transfer function in the output layer.*



7. RESULTS

In this section we present results of the proposed core sample based and hybrid approaches for in-situ permeability prediction.

7.1. Core sample based approach

For the core sample based approach we propose two prediction models CS-MVR and CS-ANN as described in section VI. We compare the proposed models with an analytically derived model called the RGPZ model, Glover et al. (2006), which is also based on core sample approach. Figures 10 and 11 shows screenshots of the in-situ permeability prediction tool that uses the proposed core sample based approach.

7.1.1. Routine air permeability prediction

Figure 13 shows a comparison of the predicted routine air permeability with the measured routine air permeability using the proposed CS-MVR model. Data from 117 core samples from 12 different wells was used for this comparison.

Figure 14 shows the comparison of predicted and measured routine air permeability for the proposed ANN based model. Figure 15 shows the comparison for the of predicted and measured routine air permeability for RGPZ model. The fit line in figures 13, 14 and 15 shows the least squares fit to the data. For a perfect fit, the fit line should fall along the 45 degree line (Y=X), where the measured and predicted values match.

Comparing figures 13, 14 and 15 we observe that the CS-ANN based model gives the best results (correlation coefficient, R = 0.92), followed by CS-MVR model (correlation coefficient, R = 0.89) and RGPZ model (correlation coefficient, R = 0.82). The CS-ANN model performs better than the CS-MVR model because the neural network is able learn nonlinear relationships between input and output vectors and hence capture the complex relationships which cannot be expressed as simple algebraic expressions. Moreover both the proposed models (CS-MVR and CS-ANN) perform better than the RGPZ model because, the proposed models incorporate the effects of microstructure and diagenesis and also distinguish between different classes of porosity using the three indices described in section IV.

7.1.2. In-situ permeability prediction

As discussed in section IV, we adopt a two-step approach. In first step we predict the routine air permeability and in the second step we add the in-situ effects to predict permeability in reservoir conditions.

Figure 16 shows the comparison of predicted in-situ permeability (at a confining stress of 4000 psi and 50% water saturation) with the routine air permeability using CS-MVR model. From the fit line and the 45 degree line (Y=X) it is observed that the predicted in-situ permeability is less than the routine air permeability, because of factors such as presence of water saturation and confining stress in reservoir conditions.

As seen in figure 11 we can change the values of in-situ parameters such as confining pressure and water saturation to observe the effects of the reservoir conditions on permeability. Figures

17 and 18 show the comparisons of predicted in-situ and routine air permeability for CS-ANN and RGPZ models respectively.

Figure 19 shows an example of how we incorporate the effect of confining pressure onto the predicted routine air permeability. As described in section IV, we characterize the pressure sensitivity of the core using the permeability measured in routine air and confined conditions. From the established relationship between pressure and permeability we can then predict permeability at any given value of pressure. From figure 19 we observe that permeability decreases with an increase in pressure which is due to factors such as reduction in pore volume. Figure 20 shows how we incorporate the water saturation effects. As described in section IV, we use the Corey equation to calculate the relative gas permeability for a given value of absolute gas permeability and water saturation. From figure 20 we observe that relative gas permeability decreases significantly as the water saturation becomes greater than 50%.

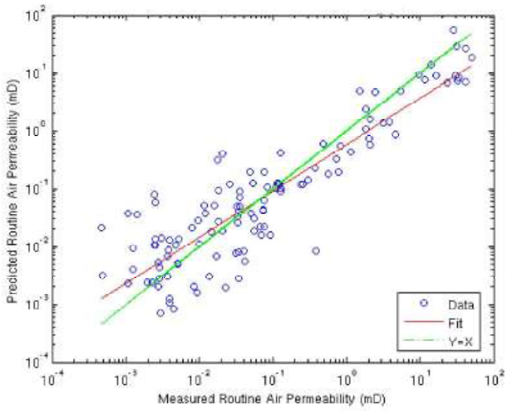
7.2. Hybrid approach

For the hybrid approach we propose two prediction models HY-MVR and HY-ANN as described in section VI. We compare the proposed models with the Timur model which is a wireline log based model. To validate the proposed hybrid approach we used wireline log and core sample analysis data from two different wells of Mesaverde tight gas sandstone reservoirs. As described in section IV the hybrid approach uses the concept of containers which are identified from logs. A number of core samples are extracted from each container. The properties measured from the core samples are extrapolated to the entire container. In-situ permeability is predicted by the proposed prediction models (HY-MVR and HY-ANN) which use the core derived and wireline log derived properties. Figure 21 shows the depth plot of permeability for “AmHunter Old Road 1” well of the Green River basin using the wireline log and core sample data from KGS (2009).

Figure 22 shows the depth plot of permeability for “Barrett Last Dance 43C-3-792” well of the Piceance basin using the wireline log and core sample data from KGS (2009). Both figures 21 and 22 show a comparison of the core measured permeability (in simulated in-situ conditions), log derived Timur permeability, and predicted in-situ permeabilities using proposed HY-MVR and HY-ANN models. From both figures it is observed that the HY-ANN model gives the best match to the core permeability followed by HY-MVR and Timur models. This is because the HY-ANN model is able to learn complex patterns of permeability distribution in the well.

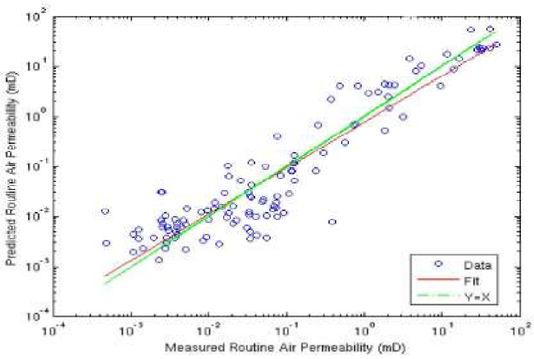
The HY-MVR model, on the other hand, provides a best estimate of the average, therefore, the distribution of the predicted values is narrower than the original data. The Timur model gives a wide variation in the predicted values because it uses fewer parameters than the other models and relies heavily on in-situ porosity. Due to a large porosity exponent in the Timur model, small variations in porosity lead to large variations in permeability. From figures 21 and 22 we observe that the hybrid approach provides a continuous prediction profile at reservoir conditions.

***FIGURE 13** Routine air permeability prediction using CS-MVR model.*



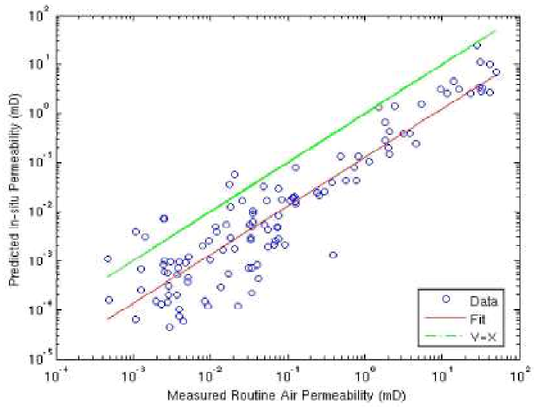
The plot shows a comparison of measured and predicted routine air permeability obtained using MVR based model. The fit-line shows the least squares fit to the data. For a perfect fit, the fit line should fall along the 45 degree line (Y=X), where the measured and predicted values match.

***FIGURE 14** Routine air permeability prediction using CS-ANN model.*



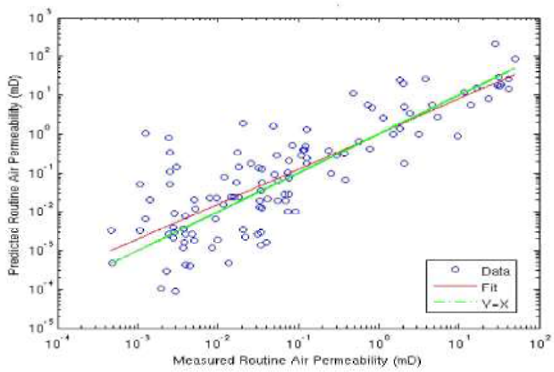
The plot shows a comparison of measured and predicted routine air permeability obtained using ANN based model. The fit-line shows the least squares fit to the data. For a perfect fit, the fit line should fall along the 45 degree line (Y=X), where the measured and predicted values match.

***FIGURE 15.** Routine air permeability prediction using RGPZ model*



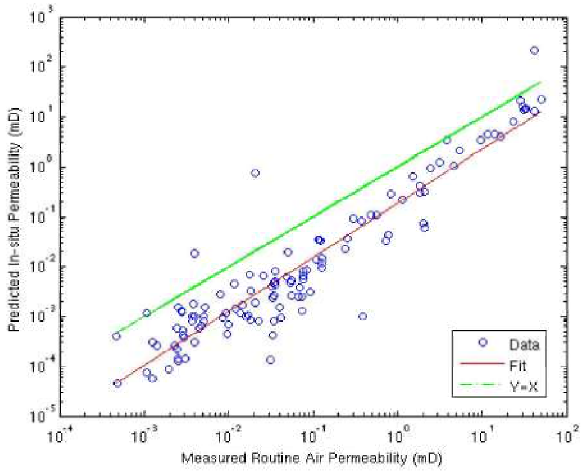
The plot shows a comparison of measured and predicted routine air permeability obtained using RGPZ model. The fit-line shows the least squares fit to the data. For a perfect fit, the fit line should fall along the 45 degree line (Y=X), where the measured and predicted values match.

***FIGURE 16.** In-situ permeability prediction using CS-MVR model*



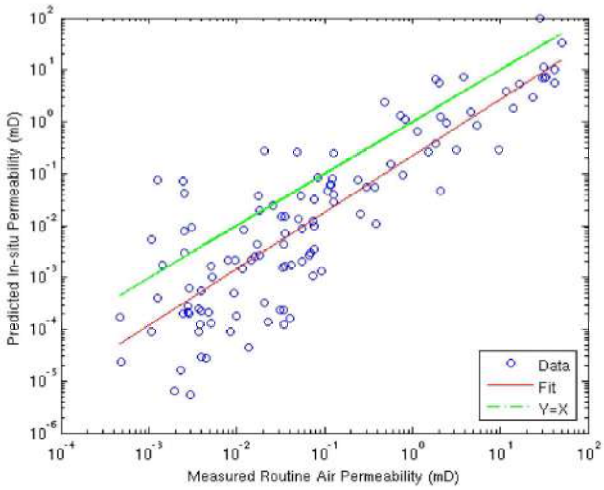
The plot shows a comparison of routine air and predicted in-situ permeability (at a confining stress of 4000 psi and 50% water saturation) obtained using MVR based model. The fit-line shows the least squares fit to the data. The fit line falls below the 45 degree line (Y=X) which shows that the predicted in-situ values of permeability are smaller than the routine air values.

FIGURE 17. *In-situ permeability prediction using CS-ANN model*



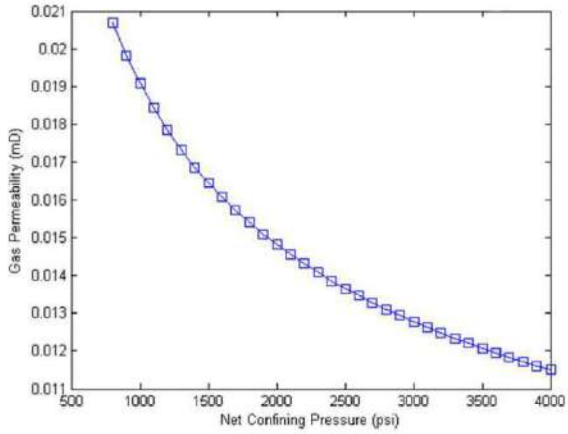
The plot shows a comparison of routine air and predicted in-situ permeability (at a confining stress of 4000 psi and 50% water saturation) obtained using ANN based model. The fit-line shows the least squares fit to the data. The fit line falls below the 45 degree line (Y=X) which shows that the predicted in-situ values of permeability are smaller than the routine air values.

FIGURE 18. *In-situ permeability prediction using RGPZ model*



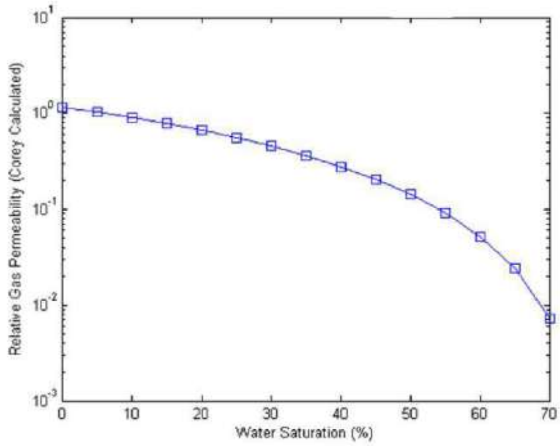
The plot shows a comparison of routine air and predicted in-situ permeability (at a confining stress of 4000 psi and 50\% water saturation) obtained using RGPZ model. The fit-line shows the least squares fit to the data. The fit line falls below the 45 degree line (Y=X) which shows that the predicted in-situ values of permeability are smaller than the routine air values.

FIGURE 19. *Example of the effect of pressure on gas permeability*



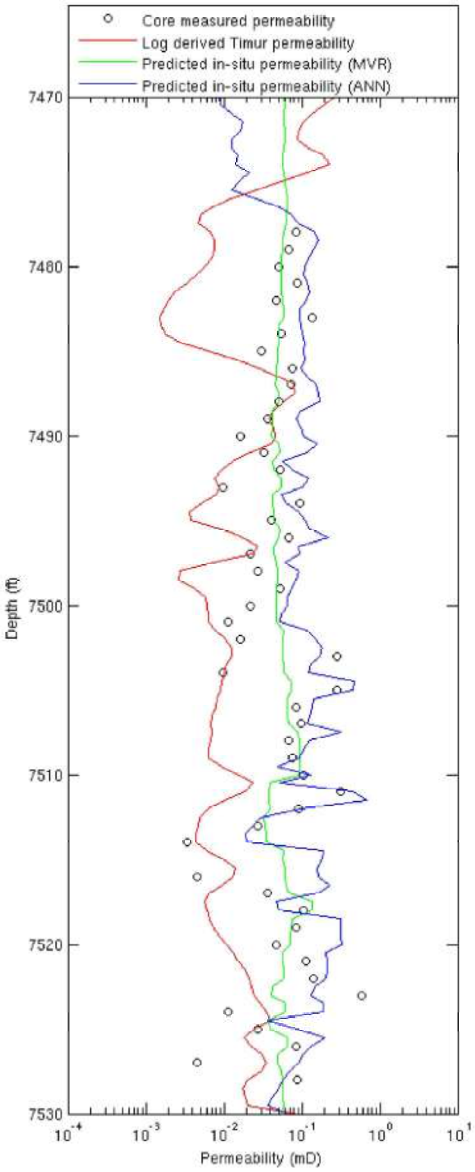
The plot shows that the permeability decreases with an increase in pressure which is due to factors such as reduction in pore volume. The pressure-permeability relationship was obtained by characterizing the pressure sensitivity of the core using the permeability measured in routine air (800 psi net confining stress) and confined conditions (4000 psi net confining stress).

FIGURE 20. *Example of the effect of water saturation on relative gas permeability*



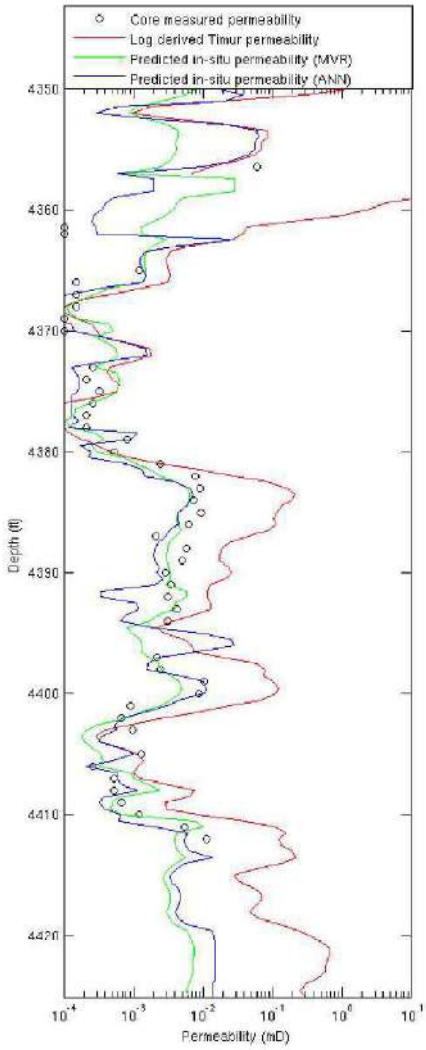
The plot shows that the relative gas permeability decreases significantly as the water saturation becomes greater than 50%. The relative gas permeability and water saturation relationship was obtained using the Corey equation.

FIGURE 21. *Depth plot of permeability for ``AmHunter Old Road 1'' well of the Green River basin using the wireline log and core sample data from KGS (2009).*



The plot shows a comparison of the core measured permeability (in simulated in-situ conditions), log derived Timur permeability, and predicted in-situ permeabilities using proposed HY-MVR and HY-ANN models. The HY-ANN model gives the best match to the core permeability followed by HY-MVR and Timur models.

FIGURE 22. *Depth plot of permeability for ``Barrett Last Dance 43C-3-792'' well of the Piceance basin using the wireline log and core sample data from KGS (2009).*



The plot shows a comparison of the core measured permeability (in simulated in-situ conditions), log derived Timur permeability, and predicted in-situ permeabilities using proposed HY-MVR and HY-ANN models. The HY-ANN based model gives the best match to the core permeability followed by HY-MVR and Timur models

TABLE 4: Comparison of models

Model	Approach	Standard Deviation	Standard Error	Correlation Coefficient
RGPZ	Core sample	21.9855	2.0326	0.8220
CS-MVR	Core sample	6.7557	0.6246	0.8940
CS-ANN	Core sample	11.8778	1.0981	0.9218
Timur	Wireline Log	0.1349	0.0199	0.5758
HY-MVR	Hybrid	0.0022	0.0003	0.7588
HY-ANN	Hybrid	0.0095	0.0014	0.8886

8. CONCLUSION

Prediction of permeability in reservoir conditions is the key to quantify the reservoir quality. Permeability depends on microstructure, diagenesis effects and in-situ conditions in the reservoirs. In this paper we described the key properties affecting permeability and proposed two in-situ permeability prediction approaches. Through empirical modeling techniques such as multivariate regression analysis and artificial neural networks we developed prediction models. The proposed models were validated with the data from tight gas sandstone reservoirs of western US basins. Results showed that the proposed models are able to capture the key properties affecting permeability in reservoir conditions and provide accurate predictions.

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DISTANCE RELAY CHARACTERISTICS SUITABLE FOR DYNAMIC LOADING

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KEYWORDS

Distance relay; Loadability limit; Lens Characteristics; MHO characteristics; Transmission line

Abstract: Modern distance relays are designed with different characteristics in order to demonstrate that they can provide better protection and at the same time results in significant improvement of the performance of distance relays during wide area disturbances by preventing the operation of distance relays under dynamic load conditions. However, blocking the operation of the distance elements if a fault occurs at this time may result in a further degradation of the system conditions. The paper discusses in detail the effect of dynamic loading on different types of distance relays characteristics and the relay loadability limits at a different power factor angle are calculated. The simulation result shows the impact of different MTA on a relay loadability limit. The comparison of MHO characteristics and lens characteristics are carried out in PSCAD/EMTDC software. The test network used in this paper is 230 kV, 300 km radial Transmission line systems.

1. INTRODUCTION

Distance Relay has widely used a protective relay in a long transmission line nowadays. The Distance Relay achieves selectivity on the basis of impedance. As the impedance is proportional to the distance between the fault point and relay so the relay is directly indicated a distance of fault location. Distance relay is always set for instantaneous operation in the first zone, delayed operation in the second zone and provide back protection in the third zone [1].

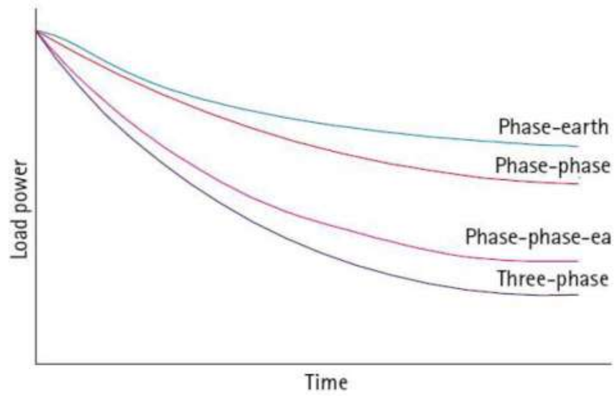
The most common use relay characteristics are MHO type. The MHO characteristic is a circular characteristic passing through R-X origin. It has an inbuilt directional feature. In MHO characteristic of distance relay maximum torque angle is generally set as line angle. The quadrilateral characteristic is most preferred when protecting short transmission lines as this provides substantial resistive coverage and arc compensation than the traditional circular characteristics [7].

Recently lenticular or lens characteristics are used for heavily loaded long transmission lines. It has more immunity to load encroachment but less coverage of fault resistance. The lens characteristics generated by merging the common area between two MHO elements [8].

2. DISTANCE PROTECTION REQUIREMENTS FOR DYANAMIC

The day to day increase of the loading of transmission lines as the power industry is undergoing fundamental changes or deregulated markets, economic and environmental requirements have to be considered when analysing the performance of distance relays, selecting protection devices with distance functions and calculating their settings [2].

FIGURE 1: *Typical power/time relationship for various fault types*



Since the dynamic stability is a function of the loading of the line and the duration of the fault, the operating time of the distance relay will affect the level of loading of the protected line. Shorter fault clearing times allow increased power transfer (fig.1) [4].

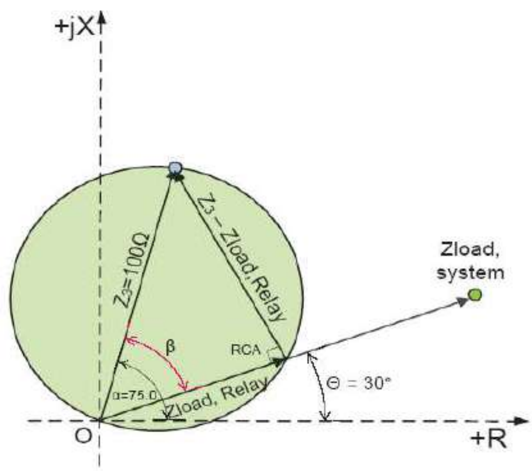
The detection of a fault and a decision to trip is made by modern distance relays in less than one cycle. However, the operating time of the relay and its give the distance of fault location are not the only factor to be considered while selecting a distance protection for a transmission line that requires dynamic loading but also the loading of transmission lines is typically limited by their rating. The thermal rating is usually based on a conservative assumption of weather conditions. Since weather conditions are continuously changing, most of the time the actual rating of the line can be significantly increased, especially if specialized monitoring equipment is being used [3]. For short transmission line transmission line load ability is decided by its thermal rating, while for medium transmission line its decided by voltage regulation and for long transmission line load ability limit decided by steady state limit.

3. LOADABILTY LIMITATIONS

In some situations, however, the power load of the line is sufficiently large that it reduces the load impedance to a point which encroaches on the relay's characteristic shape. As a result, the distance relay identifies the encroachment as a fault and consequently trips the line out of service. This is a highly undesirable operation because a heavily loaded line has been taken out of service when no real fault exists.

It is important to note that there is a difference between lines loading and relay loadability. Permissible line loading is governed by thermal ratings of the conductor and terminal equipment, as well as voltage drop and stability criteria [4].

FIGURE 2: *Calculating MVA pickup of mho element*



For Calculating the distance relay maximum loadability limit following steps to be considered [6].

Draw the zone 3 impedance vector in the R-X diagram.

Draw the load impedance vector at a specified power factor, 30o shown in fig.2

Draw a right triangle forming the 90 ° relay characteristic between the load impedance vector and the difference vector that is made up of Z3 – Zload. This is shown in fig.2

Calculate the interior angle β that is made between the load and line impedance vectors. This is done by subtracting the line impedance angle minus the power factor angle.

$$\angle\beta = \angle\alpha - \angle\theta \qquad (1)$$

Calculate the load impedance that the relay will experience at the specified power factor using right triangle properties.

$$\cos\beta = \frac{Z_{load}}{Z_3} \qquad (2)$$

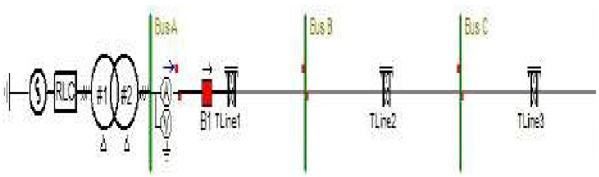
Calculate the maximum loadability of the relay in MVA

$$S_{relay} = \frac{kV_{LL}^{\ 2}}{Z_{load}^{\ *}} \qquad (3)$$

4. SIMULATED SYSTEM

In this paper three phase 230kV, 300 km, a single circuit transmission line is considered. Zone 1 cover 80km, zone 2 cover150 km, and zone 3 cover 220km of transmission line length. The various faults occur in 0.20 sec. The distance relay operates in zone 2 in 20 cycle delays and operates in zone 3 in 60 cycle delays. The system details are given in the Appendix.

***FIGURE 3:** Stimulated Systems*

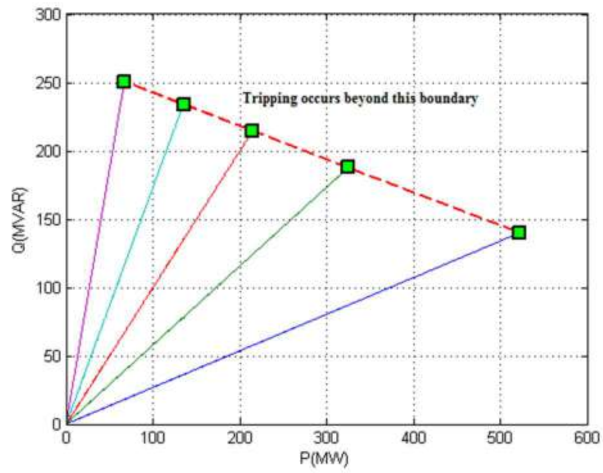


The three phase load connected at bus B and its value increased gradually to find relay maximum loadability limit for different power factor angle of load as shown below Table 1.

TABLE 1 Relay loadability for different power factor angle for Mho

Power Factor Angle	S(MVA/phase)	P(MW/phase)	Q(MVAR/phase)
0	630.46	630.46	0
15	541.04	522.60	140.03
30	375.80	325.45	187.89
45	303.77	214.79	214.79
60	270.37	135.18	234.14
75	259.53	67.16	250.68

***FIGURE 4:** P-Q diagram and loadability limit*



The shown fig.4, which emphasizes the amount of real and reactive power needed to trip a line based on zone 3 settings at different power factor. It can be observed fro Table 1 that for line, operating at unity power factor 630.46 MW/phase required.

4.1 Impact of MTA on relay loadability

The angle of maximum torque of distance relay using the mho characteristics is the angle at which it has the maximum reach. For microprocessor relays, the MTA is the same as the positive sequence line impedance angle. The

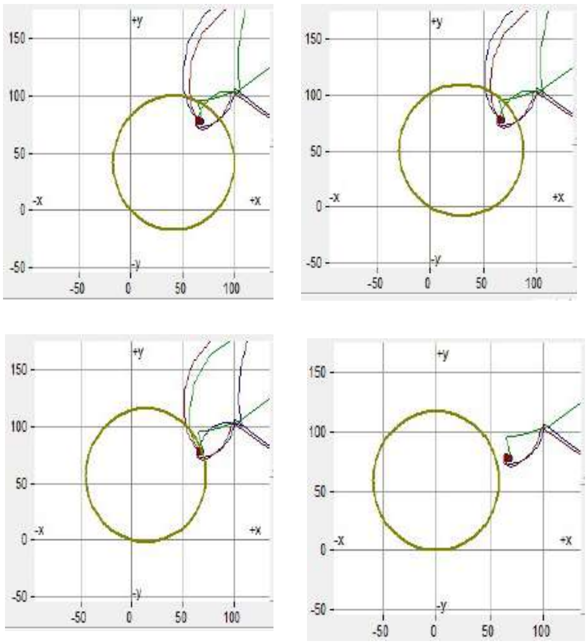
MTA or line impedance angle varies depending on the voltage level of the transmission line. For example, in the extra high voltage or EHV transmission lines, the angles are higher and for lower voltage transmission and sub-transmission systems, the angles tend to be lower because the ratio of reactance to resistance is usually lower [5].

Referencing the formula given in below [4], it can be shown that the percentage increase in MVA loading when going from a lower maximum torque angle to a higher torque angle is

$$\%increase = 100 * \left(\frac{\cos(MTA_{old} - loadangle}{\cos(MTA_{new} - loadangle} - 1 \right) \quad (4)$$

For seeing the impact of MTA on relay loadability if the load is increased above the 375.80 MVA/phase at power factor angle 30°, which is mention in Table 1 connected to the bus B, the distance relay will maloperate in zone 3. The results shown in below fig.5 relay loadability for different MTA. Results show that as the MTA of relay characteristics increase then relay loadability limit is increased.

FIGURE 5: *Relay loadability (a) MTA 45° (b) MTA 60° (c) MTA 75° (d) MTA 90°*



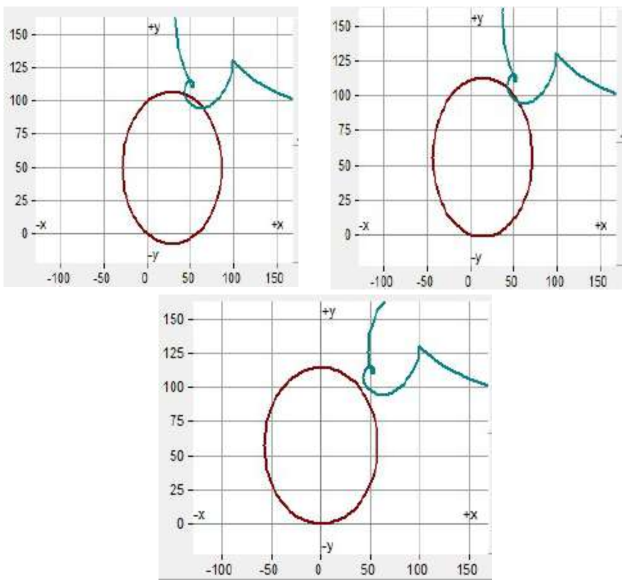
It can be shown in below Table 2. percentage MVA loading increase or decrease for different value of MTA. It can be found using the equation (4).

TABLE 2 Impact of MTA on relay loadability

MTA_{old}	MTA_{new}	% MVA increase	% MVA decrease
60°	30°	-	13.50
	45°	-	10.34
	75°	22.5	-
	90°	73.20	-

The reach of mho relay is affected in spite of the presence of fault resistance. Due to the effect of fault resistance distance relay will measure more impedance rather than actual. Therefore mho relay under reaches because of the fault resistance. The impact of MTA of relay characteristics also affect the fault resistance withstand. To demonstrate above case the single line to ground fault is created at 215km from the relay in zone 3with the R_f 25 Ω at a different MTA.

FIGURE 6 :SLG fault with R_f 25 Ω (a) MTA 60° (b) MTA 75° (C) MTA 90°



It is clearly evident that for MTA 45° and fault resistance 49 Ω if the single line to ground faults occurs in zone 3 the distance relay will under reach. The fault resistance withstands with relay characteristics increases if MTA decrease shown in below Table 3.

***TABLE 3** Fault resistance capability for different MTA with respect to MTA 60°*

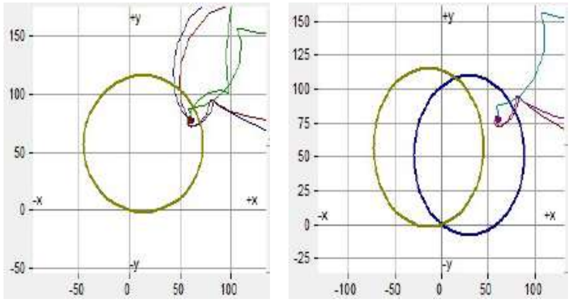
MTA old	MTA new	R_f (Ω)	% R_f increase	% R_f decrease
60°	45°	49	32	-
	75°	25	-	32.4
	90°	15	-	60

4.2 Lens Characteristics

The lens characteristic reduces the zone coverage and therefore increases the amount of permissible load. With a 'lens' characteristic, the aspect ratio of the lens (a/b) is adjustable, enabling it to be set to provide the maximum fault resistance coverage consistent with non-operation under maximum load transfer conditions. It is used for prevent the load encroachment condition which undesirable for distance relay. During the load encroachment condition distance relay will maloperate in zone 3. By using the lens characteristics the relay loadability limit increase and relay will not maloperate in zone 3. Lens characteristics are made by intersection of two mho circle.

In this paper to create the load encroachment condition for relay at substation A, the load at bus B is increased gradually. For 230 kV transmission line and for 30° power factor angle load if the load is increased 376 MVA/phase the distance relay will maloperate in zone 3 with mho characteristics but using lens characteristics relay will not maloperate because load impedance remain outside of intersection of two mho circle. Hence relay loadability limit increase as shown in below fig.7.

***FIGURE 7:** overloads condition (a) with mho (b) with lens*



The relay loadability limit of different power factor angle of load using lens characteristics is given in below Table 4. It's show that relay loadability limit of lens characteristics is more than compare to mho characteristics.

***TABLE 4** Relay loadability for dieerent power factor angle for lens*

Power Factor Angle	S(MVA/phase)	P(MW/phase)	Q(MVAR/phase)
15	9634.6	9305	2493
30	951.45	823.97	475
45	518.88	366.91	366.91
60	325.46	162.73	281.85

5. CONCLUSION

The MHO and lens types of distance characteristics analyzed in the paper demonstrate that by properly selecting and setting the distance characteristics, the user can define an optimal protection element that will provide sufficient arc resistance coverage and at the same time eliminate the possibility for tripping under maximum dynamic load conditions.The simulation result show that lens characteristics are more useful for preventing load encroachment phenomenon. This technical paper has presented the reader with valuable concepts on how to calculate the loadability limits of a distance relay. The impact of MTA on relay loadability is also described. With the increase in a MTA the relay loadability limit is increased but at the same time fault resistance coverage by the relay decrease.

APPENDIX

Parameter	Value	Unit
System Voltage	230	kV
Line Length (AB, BC, CD)	100	km
Line Positive Seq. Series Impedance	0.1236 + j0.5084	Ω/km
Line Zero Seq. Series Impedance	0.451 + j1.3277	Ω/km
Sources Positive Seq. Impedance	+ j18.28	Ω

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INDIAN PETROLEUM INDUSTRY: SOME INSIGHTS USING PORTER'S MODEL

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KEYWORDS
Petroleum, supply chain, Porter's model, India, Competition

Abstract: The purpose of this paper is to understand the competitive environment of the Indian petroleum industry and also to determine the implications of the competitive environment on supply chain performance. The Indian petroleum industry has been analysed by applying Porter's Five Forces Model and its implications on supply chain performance of the industry have been determined. As compared to discrete manufacturing supply chains, process industry supply chains are relatively less researched. Though Porter's Five Forces Model is an old concept its application to the petroleum industry especially with reference to India is new. The insights provided by this paper could be valuable to industry as well as policy makers.

1. INTRODUCTION

Process industries are a vital component of any economy. These consist of industries like basic chemicals, petrochemicals, petroleum, fertilizers and pesticides. Process industries transform raw materials into finished products on a commercial scale using a sequence of physical and chemical changes. The transformations are termed as processes and engineered in process plants (Brennan, 1998). The chemical and processing industries provide the building blocks for many products. By feeding industries and the transportation sector the petroleum industry keeps the wheels of the economy moving. Among the process industries, the petroleum industry holds critical importance with both industry and transportation dependent upon it. In a growing economy like India, the significance of this process industry cannot be overemphasized.

The oil sector in India has remained largely in the hands of the Public Sector Undertakings (PSUs). Oil and Natural Gas Commission (ONGC) is by far the biggest player in the oil exploration & production sector and has a presence in refining through its arm-Mangalore Refineries and Petrochemicals Ltd. (MRPL). The major companies in refining are: Indian Oil Corporation Ltd, Bharat Petroleum Corporation Ltd and Hindustan Petroleum Corporation Ltd. Since the opening up of petroleum sector to private sector Reliance and Essar have also appeared as important players in this sector. The Administered Price Mechanism (APM), which meant total control of government on prices of petroleum products, was formally dismantled in April 2002. Subsequent the meeting of the Empowered Group of Ministers in June 2010 pricing of petrol was freed from controls and it was decided that decontrol would also be extended to HSD pricing in due course of time.

However, major products such as Diesel, LPG (Domestic) & SKO (PDS) are still under price control. The way retail petrol prices are revised hints that the government still has some say in petrol pricing and the oil marketing companies continue to absorb a part of the under-recoveries caused by the non-revision of the selling prices.

This paper focuses on the petroleum supply chain with special reference to India and has the following objectives

- To understand the competitive environment of the petroleum industry in India by applying Porter's Five Forces Model.
- To determine the implications of the applying Porter's Model to supply chain performance of petroleum industry in India.

2. JUSTIFICATION OF THE STUDY

The present study focusing on the petroleum industry in India is justified due to the following reasons.

- Strong growth potential in India: The per capita consumption of petroleum products in India is much lower than in developed nations and even lower than developing nations like China. With the per capita consumption level in India less than 50% of that in China, a strong growth potential exists in India, given particularly a large population base of over a billion. According to World Energy Outlook 2015, India today is home to one-sixth of the world's population but accounts for only 6% of global energy use and one fifth of the population still lacks access to electricity. A comparison of figures on per capita consumption of different countries is given in Table 1.

TABLE 2: *Per capita consumption of petroleum products*

Country	Per capita consumption (bbl/day per 1000 persons)
Canada	64
US	61
Germany	31
China	7
India	3

(Source: CIA World Fact book from www.indexmundi.com)

According to the World Energy Outlook (2015), energy use worldwide is set to grow by one-third to 2040 driven primarily by India, China, Africa, the Middle East and Southeast Asia. Out of this, India contributes about one quarter, the single largest share of growth.

- Petroleum still the major energy source: Despite growing efforts to find alternate sources of energy, petroleum still remains the most widely used energy source not only in India but across the world. The consumption of petroleum products in India is shown in Table 2. Looking at the economic growth of India, the consumption of petroleum products can only increase in future.

- Contribution to resources of Indian government: The petroleum industry in India is also making substantial contribution to the resources of the central and state governments of the country. The contributions during the past three years are given in Table 3.

- Expected change in India due to liberalization: The Indian industry is undergoing liberalization and insights into the industry can help policy makers to make more effective decisions while deciding on policies for the petroleum industry. The implications of applying the model to supply chain performance also need to be understood since liberalization of this industry in India shall require it to be more competitive and supply chain performance shall be a major factor in deciding the overall performance of any oil firm.

TABLE 3: *Consumption of petroleum products in India (mmtpa)*

Petroleum Products	2011-12 (MMTPA)	2012-13 (MMTPA)	2013-14 (MMTPA)	2014-15 (MMTPA)	2015-16 (MMTPA)
LPG	15,300	16,986	18,363	19,675	20,857
MS	14,993	16,091	17,527	19,083	20,766
NAPHTHA/NGL	11,105	12,353	11,417	11,417	11,022
ATF	5,396	6,009	6,587	7,202	7,849
SKO	8,229	7,949	7,631	7,326	7,033
HSDO	64,742	65,040	68,654	72,589	76,904
LDO	415	400	400	400	400
LUBES	2,745	2,691	2,772	2,857	2,945
FO/LSHS	9,232	7,954	7,902	7,899	7,872
BITUMEN	4,628	5,254	5,541	5,732	5,971
PET COKE	6,145	6,765	7,514	8,345	9,268
OTHERS	4,869	5,445	6,127	6,109	6,085
Total POL	1,47,997	152,937	160,346	168,635	176,972

TABLE 3: *Contribution of oil sector to centre and state ex-chequer (crores of rupees)*

	2012-13	**2013-14**	**2014-15**
Contribution to central ex-chequer	142626	152900	172066
Contribution to state ex-chequer	136035	152460	160554
Total	**278660**	**305360**	**332620**

3. PAST STUDIES ON PETROLEUM INDUSTRY

The petroleum industry supply chain is more complex than either the discrete manufacturing supply chains or other process industry supply chains. The petroleum supply chain has certain distinguishing characteristics which set it apart from discrete manufacturing supply chains. Varma et. al. (2007) have tried to identify the characteristics of the petroleum supply chain with special reference to India. The option to trade or exchange crudes, intermediates and products at key points along the chain means that companies have to balance a series of complex and interlinked economic decisions to maximize their margins (Moore, 2005). The environment is dynamic and hence it requires a supply chain that adapts itself to the changes in the environment. Thus, petroleum companies require Adaptive Supply Chains (ASCs) (Tomkins, 2002).

Decision Support for Supply Chains through Object Modeling (DESSCOM) can be used to model supply chains and enable decision-making (Biswas and Narhari, 2004). Operations Research (OR) applications combined with Advanced Planning and Scheduling (APS) systems have been used to develop a vehicle routing and scheduling system (Gayialis and Tatsiopoulos, 2004). Mixed integer linear programming has been used for scheduling of lube oil and paraffin production (Casas-Liza and Pinto, 2004). Rocha et. al. (2013) have studied the problem in which crude oil is shipped from platforms to terminals using oil tankers at minimum transportation cost and used the concept of Cascading Knapsack Inequalities.

With its own typical characteristics, evaluating performance of the petroleum supply chain may not be easy. Varma et. al (2008) have proposed the use of Balanced Scorecard in conjunction with Analytical Hierarchy Process to evaluate this performance with particular reference to India. A framework for performance based strategies in the oil sector based on a case study of Norwegian oil firms has also been presented (Markeset and Kumar, 2007).

Enyinda et. al. (2011) has used AHP for modeling supply chain risk in a multinational oil firm in Nigeria. Briggs et. al. (2012) has also used AHP for determining risk in the petroleum supply chain. Ji et. al. (2015) apply a structural vector auto regression (SVAR) model, combining the global crude oil market with each emerging economy, to investigate the effects of different types of oil shocks on industrial outputs, real exchange rates, and consumer price levels in each of the BRICS countries.

The petroleum industry faces typical logistics problems, too. In case of oil exploration, there is a known limited storage capacity at the shorebases, on vessels and at the platforms. Vessel size is constrained because of the physical limitations at the shorebases and platforms during the loading/unloading processes. ExxonMobil Corporation outsourced its platform replenishment operations in the US Gulf of Mexico to a division of Baker Energy Corporation (Ross et al., 2007). By training and coordinating the workforce and activities of several local service providers at Penglai 19-3 field in Bohai Bay, on the Northern Sea, ConocoPhillips' largest offshore discovery in China, the *supply chain* manager was able to craft a suite of tailored services that satisfied its core logistic requirements (Hoffman, 2004).

Arora (2015) has studied the oil industry literature to find the tools and techniques used by upstream oil companies for investment decision making. In case of the petroleum industry, one needs to make quick "make versus buy decisions", seize market opportunities where they exist and optimize the use the company's physical assets from refineries and terminals to ships and barges (Moore, 2005). This is possible only if timely information is available. Geographical Information Systems (GIS) have become extremely sophisticated and are used for everything from integrity management to emergency response and asset management in the oil and gas industry (Cobbs, 2006). Even purchase of crude oil requires a plethora of information. Apart from price fluctuations, they have to take into account transportation and storage costs. Different refineries produce different products making some of the crudes more suitable than others (Tierney, 2004). A digital pipeline could be developed through the integration of GIS with other systems such as asset management and accounting (Maggio, 2007).

In India, Bharat Petroleum Corporation Ltd (BPCL) has successfully implemented SAP. The major issues in ERP implementation in BPCL were related to choice of vendor, implementation and culture (Ravichandran, 2003). Datta (2009) has studied the supply chain optimization process at BPCL which has been enabled through the Supply Chain Optimisation Department in the organization.

Midttun et. al (2007) have looked at integration of corporate governance with other strategic elements in the North Sea offshore petroleum industry. McSweeney and Worthington (2008) have studied the role of oil as a risk factor in the stock returns in Australia. Edwards (2008) has researched on knowledge management in the energy sector of which petroleum industry is an integral part.

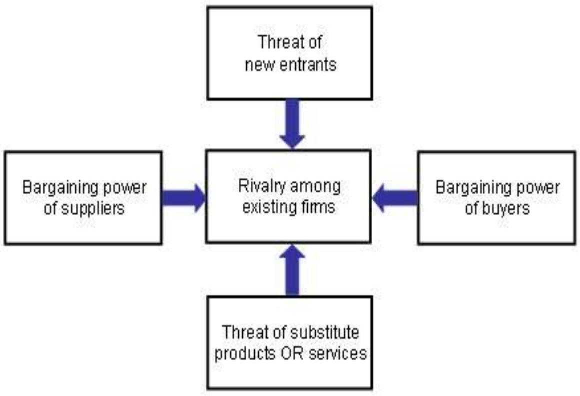
Government regulation has an important role to play in the growth and performance of any industry. Lin (2014) argues that both UK and Chinese governments have sought an increase in tax contributions from the corporate sector in exchange for specific capital investments that will address the challenges of overall decline in domestic oil production and new field exploration. This novel scheme raises concerns for fair competition in the upstream market.

Hokroh (2014) has applied Porter's Five Forces Model to the global petroleum industry to determine its competitiveness. However, this is not with reference to any particular country. Based on the literature review it seems that the Porter's Five Forces model has not been explicitly applied to the petroleum industry in India by any researcher.

4. SUITABILITY OF USING PORTER'S MODEL

According to Michael Porter, in any industry, the rules of competition are embodied in five competitive forces: the entry of new competitors, the threat of substitutes, the bargaining power of buyers, the bargaining power of suppliers, and rivalry among the existing competitors. The collective strength of these forces determines the ability of firms in an industry to earn, on average, rates of return on investment in excess of cost of capital (Porter, 1979). Porter's Five Forces Model is shown schematically in Figure 1.

Figure 2 *Porter's five forces model (Michael Porter, 1979)*



The Five Forces model is based on microeconomics. The model allows systematic and structured analysis of market structure and competitive situation. Application of this model will help in better understanding of the competitive position of the petroleum industry by comparing the impact of competitive forces on the organization versus their impact on the competitors. This will help in understanding potential future attractiveness of the industry (Varma, 2008). By understanding the impact of the Five Forces, organizations can develop options to influence them in a way that improves their own competitive position. The model will also help in providing insights into performance issues of the petroleum companies in India. Porter's Model has been extensively used in literature. Selected applications have been given in Table 4.

TABLE 4: *Selected applications of porter's model*

	Researcher (Year)	Application
1.	Eppinik, D Jan (1987)	Insurance
2.	Fahy, John (1993)	New Europe
3.	Henry, C Michael	Inner city
4.	Kling, James A and	US airline
5.	Dobni, Dawn and	Business schools
6.	Patrick Asubonteng et	Medicare health
7.	Sheppard, Lorraine	Physiotherapy
8.	Clare E Williams, Guy	Leisure industry
9.	Jasimuddin, Sajjad M	Country of Saudi
10.	Siaw, Irene (2004)	Banking industry
11.	Carle, Gian et	Fuel cell cars
12.	Smith, Alan D (2006)	Banking
13.	Vega-Rosado and Luz	Country of
14.	Hopkins, Harold	Robotics industry
15.	Hokroh, Mohammed	Global

5. APPLYING PORTER'S MODEL TO THE INDIAN PETROLEUM INDUSTRY

The Five Forces of Porter's model has been discussed in the following section with respect to the petroleum industry in India.

5.1 Entry of new competitors

The following points related to the entry of new competitors in the market are pertinent to the petroleum industry.

- Economies of scale: Economies of scale are important in bringing down average costs of production. In the petroleum industry, the products are functional in nature and profit margins are small. For a new entrant, therefore, economies of scale are particularly relevant in petroleum industry to bring down costs and also to make sizeable profits. This also means that the entrant has to seize a substantial market share while existing players have to retain customers, in order to utilize economies of scale. Estimated market shares for the major oil marketing companies for the year 2014-15 are: IOCL (43.4%), BPCL (20.2%) and HPCL (18.6%) (http://petroleum.nic.in).

- Access to distribution: In the petroleum industry, the distribution system is an important determinant to successful supply chain management as petroleum products are used by the common man. This can be a time consuming and capital intensive process for a large country like India. The total number of retail outlets in India as on 1.4.2014 were 51870 (http://ppac.org.in). These distribution points have to be well stocked with product throughout the year. Any disruption in supplies can cause panic among the general public. Public sector companies in India have a well established distribution system. For a new entrant putting up such a system will not be easy.

- Government policies: Government policies can play an important role in deciding the entry of competitors. In fact, in India these policies have played a major role in thwarting entry of fresh competitors in the downstream sector of the petroleum supply chain. The Indian government provides subsidies to the Public Sector Undertakings (PSUs). During the year 2013-14, the total subsidies provided for PDS Kerosene and domestic LPG under the Subsidy Scheme, 2002, were Rs 2580 Crore. Subsidy provided on Diesel during 2013-14 was Rs 8.39 per litre. (http;//.ppac.org.in). Such subsidies are not made available to private sector players who suffer a big disadvantage finding it infeasible to compete with the PSUs. The failure of Reliance to enter into the petroleum retail market in a big way many years ago is a glaring example of the effect of government policies on competition.

5.2 Bargaining power of suppliers

The following points related to bargaining power of supplier are pertinent to the petroleum supply chain.

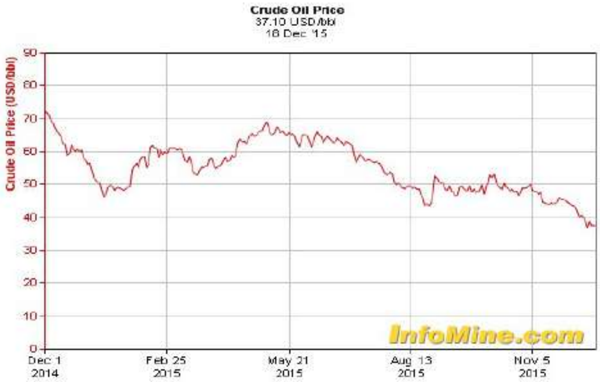
- Differentiation of inputs: The major input to the petroleum industry is crude oil. Crude oils vary from source to source and refining them can produce different composition of light, medium or heavy distillates. Thus, differentiation in inputs plays an important role in the supply chain. The role of differentiated inputs becomes more important because a steady supply of these inputs needs to be maintained for maintaining continuous processing in the refineries.

- Switching costs of suppliers: Switching costs for crude suppliers are small and they can easily switch from one petroleum firm to the other unless there are long term agreements between the two parties involved. This puts them in a strong position vis-à-vis the downstream petroleum firms. This is very relevant to India as the country depends heavily on imported crude. According to a 2013 report of Business Standard, India imports about 79% of its crude oil requirements.

- Presence of substitutes: Petroleum remains the predominant source of energy for the transport and industry sectors. The current Indian government has ambitious plans for renewable energy. According to a Business Standard report (2015), India is aiming to add 175,000 Mw of capacity from clean energy sources by 2022 of which 60 per cent would be from solar energy, 30 per cent from wind and the balance from biomass and small hydro. However, installation of these alternate sources of energy will take time. Moreover, for the transport sector neither of these sources of energy seems to be feasible in the near future. Hence, petroleum products are likely to remain in demand.

- Impact of inputs on costs in the supply chain: In the refinery, crude oil undergoes fractional distillation to produce various petroleum products. Since crude is the major input for the petroleum supply chain its impact on the cost of the supply chain is substantial. In case of India, most of the crude is imported placing it at the mercy of other nations. This factor has tremendous impact on the supply chain costs in India. Crude prices keep fluctuating and this is shown in Figure 2.

FIGURE 3 Fluctuation in crude oil prices



(Source: www.infomine.com)

- *Supplier concentration*: Supplies of crude are concentrated within a small group of nations, especially the OPEC countries. The international prices of crude are largely determined be this cartel as they control major portion of crude oil production. Since India is heavily dependent on crude imports supplier concentration puts India in an especially vulnerable position.

5.3 Threat of Substitutes

The following points related to substitutes for petroleum are relevant to the petroleum supply chain.

- *Price performance of substitutes*: Substitutes to petroleum products like solar energy had not been commercially viable for a long time. However, price performance of solar energy is now much better. According to a report by Crisil & PHD Chamber (2015) average solar tariff rates have declined from Rs. 15 per kWh to Rs. 8 per kWh. According to the same report, wind power is now gaining cost parity with conventional energy sources. Moreover, wind-power producers get a generation-based incentive (GBI) of 50 paise/kWh subject to a maximum of Rs.1 crore per Mw over a period of 10 years which is luring them to set up wind power plants. At the moment, the demand for petroleum products shows no sign of diminishing. The picture will become clearer when the government's ambitious plans for renewable energy materialize.

- *Switching costs*: Switching from petroleum products to other forms of energy can be difficult if the equipment is designed to work on petroleum, e.g., in the transport sector. However, for other uses in industrial and domestic sector switching costs are not very high.

5.4 Bargaining power of Buyers

The following determinants of buyer power are relevant to the petroleum industry.

Buyer switching costs: Switching costs for the retail buyer are low as substitute petroleum products from competing firms are freely available in the open market. However, at the moment most of the retail distribution of petroleum products is being done by Public Sector Undertakings. Despite dismantling of the Administered Price Mechanism petroleum prices are still influenced by government and there is little choice for the customer as all the companies' market products at more or less the same price.

At the firm level, as already mentioned, nature of crude can vary from source to source. Even though, various sources of crude do exist, the choice of crude can somewhat limit the freedom of oil refining companies to choose the source depending on the capability of the refinery to refine different types of crude. Hence, bargaining power of downstream petroleum firms for sourcing crude would depend on the refining capability of their refineries.

Brand identity: Brand identity is low for petroleum products in India since these are functional products and downstream petroleum companies have not attempted seriously to differentiate their products. Though firms do attempt differentiation by using additives to improve performance of fuel, such differentiation is quickly copied by competitors nullifying the benefits of differentiation. In the mind of the Indian customer there is little difference between the products sold by the different PSUs.

Impact on performance: The impact of the quality of petroleum products on performance of equipment and vehicles is high. Purity of product is especially significant for optimum performance of equipment. Impure product can not only reduce performance but may be detrimental to the equipment too. Adulteration of product is rampant at retail outlets since these are normally operated by private businessmen and all the PSUs seem to be equally vulnerable to this practice. In India, adulteration of petrol and diesel is a big ticket scam that involves an annual recurring loss of at least Rs 10,000 crore to the exchequer (Ramchandran, 2005).

5.5 Industry rivalry

The following points related to competition within the petroleum industry are pertinent to the petroleum supply chain.

- *Industry growth:* The Indian economy has been steadily growing and demand for petroleum products is increasing to cater to this development. According to a report by Times of India, in the year 2016 India's economy is estimated to grow at about 7.7% outpacing China. Naturally, petroleum industry will also grow in the country. However, the competition is largely limited to the PSUs especially in the downstream supply chain.

- *Intermittent overcapacity*: In terms of the demand for petroleum products within the country, there is excess capacity of refining. However, this is being utilized for producing petroleum products for exporting to other countries. India is a net exporter of petroleum products though it imports crude. However, firms need to be cost competitive in order to export. India's oil refining capacity amounted to 215 MMTPA (Million Metric Tonne Per Annum) in Apr 2014 placing India in the fifth position in the world after the United States, China, Russia and Japan. Total refined crude output was 223 million tons in 2014-15, i.e. over 100% of installed annual capacity (www.knowindia.net). As on 1.4. 2012 India had a total of 23 refineries of which 18 are owned by Public Sector Undertakings, 3 are in the private sector and 2 are joint ventures (https://data.gov.in)

- *Exit barriers*: Being a player in the petroleum industry requires high investments and fixed costs. Once such huge investments have been made exiting the scenario is not easy. In India, exit barriers are high for any industry due to government regulations and this becomes worse for petroleum due to high investments making it unattractive for foreign investors.

Application of Porter's model to the petroleum industry and the resulting implications on performance of the supply chain have been summarized in the Table 5 as in appendix 1.

6. ROLE OF GOVERNMENT POLICIES

Government policy is an important component of Porter's Model. The role of government policies in the petroleum industry requires separate mention. Government policies can go a long way in defining the competitive scenario of an industry in a country. This has been the case with India too. Until March 2002, the prices of petroleum products were decided by the government under a system termed as Administered Price Mechanism (APM). The APM was formally dismantled in 2002. Moreover, distribution of petroleum products and exploration are now open to private sector players. A brief comparison of the situation during pre-reform period with the post reform period has been given in Table 6.

TABLE 6: *Comparison of pre-reform situation and post-reform situation in petroleum industry*

Area of concern	Situation pre- reforms	Situation post-reforms
Private participation in distribution	Private participation not allowed. Only the government owned companies had retail outlets.	Private participation allowed. New players, viz, Reliance, Essar and Shell took active interest in setting up retail outlets. But subsidies provided by government on diesel and petrol squeezed their margins and they were unable to compete when crude prices spiraled up. Reliance and Essar closed all their retail outlets during this time.
Private participation in exploration	Private participation was allowed but was very limited.	Real encouragement to private sector participation began with the announcing of New Exploration and Licensing Policy (NELP). Auction of oil and gas blocks was done in 2012 during NELP IX.
Pricing of petroleum products	Pricing based on cost-plus expenses. No incentive for firms to improve performance.	Pricing supposed to be based on market forces. However, this does not exist. APM has entered through the backdoor in a non-transparent form.
Subsidies	Kerosene and LPG highly subsidized.	After dismantling of APM in 2002 it was expected that subsidies would be reduced gradually and then eliminated. However, they still exist. The value of subsidy for 2011-12 for PDS SKO and LPG was Rs 60,349 Crore

7. CONCLUSION

This paper has attempted to gain insights into the petroleum industry to better understand the competitive situation in India. The implications of the competitive forces on the performance of the supply chain have also been enumerated. Petroleum companies need to focus on market share and ensure a steady supply of products and raw material through an efficient transportation system and a geographically dispersed network of retail outlets. Inventory holding costs need to be cut down and crude has to be sourced at competitive prices. This can be done by effective usage of information technology.

From a policy perspective, the government needs to provide a level playing field so that private players can also compete in the market. Administered Price Mechanism needs to be dismantled, both in letter and spirit in order to allow prices of petroleum products to be determined by market forces. Subsidies provided to PSUs need to be eliminated. Only by doing this can the true benefits of liberalization be realized? Also, the government needs to reduce dependency on imported crude by encouraging oil exploration by private companies. All this will help in improving competitiveness of the petroleum industry in India.

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APPENDIX

TABLE 5: *Application of Porter's model to petroleum industry and implications to the supply chain*

Competitive force: Entry of new competitors		
Determinants of entry	Relevance to petroleum supply chain	Implications for performance of supply chain
Economies of scale	Economies of scale are essential in this industry.	Economies of scale can be availed if the firm has adequate market share. Thus, firms need to retain customers and build *market share*. CRM is important.
Access to distribution	This is a pre requisite since product is to be sold to the general public.	The distribution system needs to be geographically spread out. The selling points need to have constant supply of product. This requires firms to have a *steady supply of product* and an *efficient transportation* system.
Government policies	Indian government provides subsidies to PSUs in order to keep market prices under control. There is cross subsiding of products. Kerosene and LPG are subsidized at the cost of petrol and diesel.	The policy stifles competition since private players are not supported by the government making it infeasible for them to compete in the market. Subsidies must be completely stopped so that *private players get a level playing field* APM has to be completely dismantled not only in letter but also in spirit. This will improve SCM performance.
Competitive force: Bargaining power of suppliers		
Determinants of bargaining power	Relevance to petroleum supply chain	Implications for performance of supply chain
Differentiation of inputs	Differentiation of inputs exists as different crudes may give different percentage of light, medium or heavy distillates on refining.	The petroleum supply chain requires *constant supply of raw material*. Differentiation in inputs makes the situation more complicated as it limits the available suppliers. Firms need to have long term agreements with crude suppliers but this is difficult due to *highly fluctuating crude prices.* Since India depends heavily on imports this becomes especially relevant. Having refineries capable of refining crudes of different types can make things easier.
Switching cost of suppliers	Switching costs for crude suppliers while changing from one petroleum firm to another is small.	Suppliers are in a strong position due to low switching costs. This makes the industry supply chain *vulnerable to crude suppliers.*
Presence of substitutes	Though Indian government has ambitious plans for renewable energy it will take time. Commercially	The petroleum supply chain is highly vulnerable to *fluctuating crude prices*. India needs to build *indigenous sources* of crude so that its dependency on imported crude is reduced.

	viable substitutes to crude do not exist for transport sector. India remains heavily dependent on crude suppliers	*Supplies of petroleum products are critical* to the nation. Dependence on imports results in formation of heavy safety stocks. All these three determinants put the crude suppliers in a strong position.
Impact of inputs on costs	Crude constitutes a major portion of input cost making the impact substantial.	
Supplier concentration	Prices of crude are being controlled by a group of suppliers.	
Competitive Force: Substitutes		
Determinants of threat of substitutes	Relevance to petroleum supply chain	Implications for performance of supply chain
Price performance of substitutes	Price performance of substitute sources of energy is much improved now. However, products from one oil company can easily substitute products from another company.	Petroleum industry has been in a strong position till now. In the near future, the supply chain shall have to cater to *increasing demand*. This has implications on availability of *raw material, distribution and transportation*. Availability of *renewable sources* might modify the picture.
Switching costs	Switching over to other forms of energy in the transport sector is not feasible at the moment. For other uses switching is not difficult.	
Competitive Force: Buyers		
Determinants of buyer power	Relevance to petroleum supply chain	Implications for performance of supply chain
Switching costs	Switching costs for the retail buyer are low in terms of switching from one oil company to another. Switching cost of downstream petroleum companies as buyers of crude oil is relatively high as refineries often are not capable of refining different types of crudes.	Oil companies need to ensure that they are *competitive in terms of cost and quality of product* else they will lose market share. *Customer relationship* becomes very important. Flexibility in refining capability needs to be looked at.

Brand identity	Brand identity is not very important as it is not easy to differentiate on product features.	Purity of product as this is a major issue in the country. Hence, companies can *differentiate on purity*, if possible. Requires more stringent implementation *of testing and control* of product quality at retail outlets. Petroleum companies need to do more in *R & D* to differentiate their product.
Impact on performance	Impact of quality of product on equipment performance is high.	
Competitive Force: Industry competition		
Determinants of industry rivalry	Relevance to petroleum supply chain	Implications for performance of supply chain
Industry growth	Industry growth is high. However, rivalry is largely confined to PSUs.	Growing industry must be accompanied with *policy measures* giving a level playing field to private players fuelling competition and improving performance.
Intermittent overcapacity	Overcapacity exists but is utilized for exports.	Firms must be able to compete on *cost and quality* in order to export.
Switching costs	Switching costs are low for buyers making rivalry more intense with focus on cost cutting.	Companies need to control costs by *managing transportation and inventories efficiently* and *sourcing crude at competitive prices*.
Information complexity	Information complexity is high making use of IT extremely important.	*Extensive use of IT* is required by oil companies to bring about visibility in the supply chain and for *optimizing* the use of resources in a dynamic environment. An *Adaptive Supply Chain* is required.
Exit barriers	High exit barriers due to massive investments required in asset creation	*Assets need to be fully utilized* in order to create a high performance supply chain.

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COMMODITY HEDGING THROUGH ZERO-COST COLLAR AND ITS FINANCIAL IMPACT

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KEYWORDS
Options,
put option;
call option,
zero-cost collar,
NYMEX

Abstract: Option Derivatives appeared in 1990´s and became popular tool of hedging and risk management. In this paper, the authors seek to study the zero cost collar option contracts for commodity hedging and its fair valuation and accounting. The paper underlines the main advances in hedge accounting proposed by IASB & IFRS 9 and tests the effectiveness of zero cost collar option strategy on NYMEX WTI crude oil in the backdrop of falling commodity prices. We underline that, while the results have a great significance from an economic viewpoint, they may also be utilized for hedge accounting purposes & accounting for time value of zero cost collar strategy.

1. INTRODUCTION

At the time of the U.S. shale boom, the fortune had favoured the bold drillers who discovered and pumped crude oil the fastest. In 2015, under the backdrop of falling crude oil prices, the winners were Oil & gas producers like Pioneer Natural Resources who had shielded themselves from the tumbling crude oil prices through use of derivative transactions. Using such transactions (refer Table 1), the Texas-based firm had locked in a minimum price for its year's production whereas its rivals were selling crude oil at the market price of around $30/bbl, which was not enough to cover the cost of drilling new wells.

[1] When NYMEX price is above call price, Pioneer receives call price. When NYMEX price is between put and call price, Pioneer receive NYMEX price. When NYMEX price is between the put and short put price, Pioneer receives put price. When NYMEX price is below the short put price, Pioneer receives NYMEX price plus the difference between put price and short put price.

[1] Parties have the option to extend 5000 BPD of 2015 collar contracts with short puts for an additional year with a call price of $100.08/bbl, a put price of $90/bbl and a short put price of $80/bbl.

In 2014, about 15% of the Pioneer's production was hedged by swaps, which locked in a $96.31 sale price. However, most of the company's hedges were conducted through three-way collars, which involve selling a call, buying a put, and selling a put. These collars did not cost anything and provided upside to rising crude oil prices, as well as downside protection, upto a point. The fact that the downside protection was limited started to become a point of contention as Crude oil prices continued to fall well below the short put prices in the year 2015 which exposed Pioneer, and others using this hedging technique, to unexpected downside risk. As a result Pioneer restructured its hedging technique for the following years as shown in Table 2:

Oil & Gas companies like Pioneer had no downside risk on its hedged volumes where it used swaps as a hedging technique. However, with the collars it was 100% protected only if NYMEX WTI Price falls below $70 and stayed above the $50/barrel of the short put. The protection provided by these hedges weakens once NYMEX WTI Price fall below that point, meaning Oil & Gas companies receives less money per barrel as NYMEX oil prices keep falling.

Oil & Gas firms around the world hedge production in order to protect themselves from the volatility of crude oil prices. According to risk management theories, to avoid volatility firms hedge optimally. Firms are also able to reduce the cost of financial distress and corporate tax through hedging (Smith & Stulz, 1985). Myers and Majluf (1984) studied that hedging facilitates in maintaining cash flows to finance investments internally. But not all hedges work the same. In fact, some hedges are now becoming a liability instead of insurance. Extensive uses of collars hedges are leaving such companies open to more downside risk than expected, which is now strangling their stock prices.

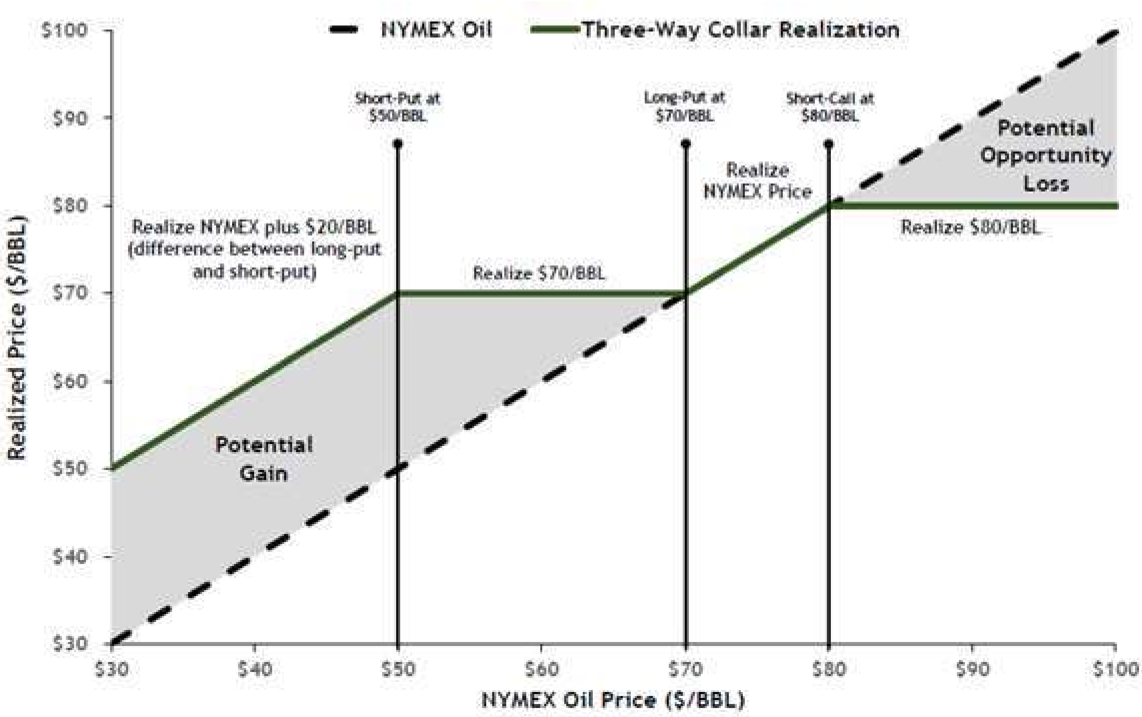
TABLE 1: *Pioneer Natural Resources: Open Commodity Derivative Positions as of 10/30/2014*

Oil	Q4 2014	2015	2016
Swaps- WTI (BPD)	15,000	-	-
NYMEX WTI Price ($/bbl)	$96.31	-	-
Three Way Collar (BPD)[1],[2]	69,000	95,767	70,000
NYMEX Call Price ($/bbl)	$114.05	$99.36	$96.86
NYMEX Put Price ($/bbl)	$93.70	$87.98	$85.62
NYMEX Short Put Price ($/bbl)	$77.61	$73.54	$74.45
% of Total Production	**~85%**	**~85%**	**~45%**

TABLE 2: *Pioneer Natural Resources: Open Commodity Derivative Positions as of 10/30/2015*

Oil	Q4 2015	2016	2017
Swaps- WTI (BPD)	82,000	4,475	-
NYMEX WTI Price ($/bbl)	$71.18	$59.00	-
Three Way Collar (BPD)[1,2]	15,000	101.806	34,000
NYMEX Call Price ($/bbl)	$97.69	$75.93	$70.42
NYMEX Put Price ($/bbl)	$82.97	$65.30	$57.65
NYMEX Short Put Price ($/bbl)	$69.67	$46.08	$47.65
% of Total Production	**~90%**	**~85%**	**~20%**

FIGURE 1: *Three Way Collars ($50 by $70 by $80) to protect downside while providing upside exposure*



In view of above background, this paper seeks to study the zero cost collar option contracts for commodity hedging and its financial impact analysis. This paper has been structured as follows: Section 2 explains briefly the literature. Section 3 describes briefly the Zero Cost Collar Hedging technique and underlines the main advances in hedge accounting proposed by IASB & IFRS 9 & describes briefly the hedge accounting under IFRS 9 and offers an overview of the traditional methods currently adopted by corporations for testing the effectiveness of their hedging strategies; Section 4 illustrates hedging of NYMEX WTI crude oil price with the collar option and applies hedge accounting treatment of derivatives from an IFRS 9 perspective. Further hedge effectiveness assessment is performed using Scenario analysis method of economic hedge effectiveness testing, and carry out Fair valuation and accounting for time value of zero cost collar hedging; and Section 5 collects some concluding remarks.

2. LITERATURE REVIEW

The implementation of hedging strategies leads to risk mitigation or not is still puzzling. Modigliani and Miller (1958) postulated that the financial risk management activities of a company are irrelevant to shareholder wealth since they have access to same risk management tools as corporate managers, hedging activities may potentially be value-increasing by mitigating a series of market imperfections. Stulz (1984) and Geczy *et al.* (1997) among others have conducted research on these hypothetical rationales for corporate risk management. They found numerous valid reasons why companies should consider hedging to maximize shareholder wealth by reducing costs related to financial distress, underinvestment problems and taxes. If we consider that hedging activities may be value enhancing due to existing market imperfections, investors should consider the information related to hedging strategies while valuing the firm.

Allayannis and Weston (2001) directly test the relation between firm value and the use of foreign currency derivatives. Empirically studying a sample of 720 large firms between 1990 and 1995, they found that the value of firms that hedge, on average, is higher by about 5%. This hedging premium is statistically and economically significant. Carter et al (2005) studied the case of fuel hedging for a sample of U.S. airlines and report an even higher hedging premium of about 14%. They show that this financial risk is economically very significant for airlines. Moreover, they argue that hedging allows airlines to expand operations when times are bad for the industry, hence mitigating the underinvestment problem. Apparently, these issues are sufficiently important in this industry to allow a large hedging premium.

However, the interpretation of these results is debated. Guay and Kothari (2003) studied the economic effects of derivatives positions for a sample of nonfinancial derivatives users. They conclude that potential gains on derivatives are small compared to cash flows or movements in equity values, and possibly do not have an effect of the claimed magnitude.

Several features of Oil and Gas Companies make it particularly suited for an analysis of risk management policies. The volatility of crude prices is the prominent feature. This paper is focusing on implication of zero-cost collar hedging on the value of the firm. Options are the most versatile instrument and to make option strategies profitable, it is important to know not only the potential profit that can be earned by well-planned strategy, but also to understand how these investment instruments work and the risk included (Fontanills, 2005).

Hedging by options is not broadly used as forwards, it has gained popularity through the zero-cost option structures. A package with zero-cost consists of zero-cost option structures, where underlying assets are foreign currencies, currency futures, commodities, securities or securities in other than domestic currency (Hull,2002).

3. ACCOUNTING STANDARDS – IAS 39 & IFRS 9

The International Accounting Standards Board (IASB) had issued Statement 39, or IAS 39, to make an entity's exposure to its derivative positions more transparent. Prior to IAS 39, most derivatives were carried off-balance sheet and reported only in footnotes to the financial statements. The introduction of IAS 39 for International Accounting Standards reporting has radically changed the recognition of derivatives. Both these standards require derivatives to be recorded in the balance sheet (as assets or liabilities) at fair value.

Derivatives that are not designated as hedges must be adjusted to fair value through income. Depending on the reason for holding the derivative position and the derivative's effectiveness in hedging, changes in the derivatives' fair value are recorded either in the income statement (in the case of a fair value hedge) or in a component of equity known as other comprehensive income - OCI (in the case of a cash flow hedge).

Changes in fair value of derivatives that are considered to be 'effective'3 for hedging aim will either offset the change in fair value of the hedged assets, liabilities or entity commitments through earnings or will be recorded in OCI until the hedged item is recorded in earnings. Any portion of a change in a derivative's fair value that is considered to be ineffective,4 may have to be immediately recorded in earnings. Any portion of a change in a derivative's fair value that the entity has elected to exclude from its measurement of effectiveness, such as the change in time value of options contracts, will be recorded in earnings. Consequently, unless they are designed as a part of a hedging relationship which qualifies for hedge accounting treatment, derivative instruments can create additional earnings volatility. Many corporations find this volatility undesirable due to the adverse impact it may have on the views of rating agencies, analysts and investors. By applying hedge accounting treatment, managers may avoid this additional volatility.

[3] **Effective part** represents the portion that is offset by a change in fair value of the hedged item.

[4] **Ineffective part** represents the portion of the change in fair value of the hedging instrument that has not been offset by a change in fair value of the hedged item.

Hedge accounting is elective, but the problem is that companies must qualify for this treatment. To qualify, the manager must measure the effectiveness of the hedge at least each reporting period for the entire life of the hedge relationship.

In November 2013, the International Accounting Standards Board (IASB) published IFRS 9 Financial Instruments (Hedge Accounting and amendments to IFRS 9, IFRS 7 and IAS 39). Most changes relate to new hedge accounting requirements developed from the proposals in Exposure Draft ED 2010/13 Hedge Accounting5, issued in December 2010 as part of the third phase of the IASB's project to replace IAS 39 Financial Instruments: Recognition and Measurement.6

Derivatives & Hedge accounting under IFRS 9

IFRS 9 Financial Instruments is a complex standard which establishes accounting principles for recognising, measuring and disclosing information about financial assets and financial liabilities. IFRS 9 is remarkably wide in scope and interacts with several other standards (see Figure 2)7.

Under IFRS 9, Hedge accounting modifies the normal basis for recognising gains and losses (or revenues and expenses) associated with a hedged item or a hedging instrument to enable gains and losses on the hedging instrument to be recognised in profit or loss (or in OCI in the case of hedges of equity instruments) in the same period as offsetting losses and gains on the hedged item. Hedge accounting takes two forms under IFRS 9[8]:

2.1.1 *Fair value hedge* – The objective of the fair value hedge is to reduce the exposure to changes in the fair value of an asset or liability already recognised in the balance sheet. Therefore, the aim of the fair value hedge is to offset in profit or loss the change in fair value of the hedged item with the change in fair value of the hedging instrument (e.g., a derivative).(See Figure 3).

2.1.2 *Cash flow hedge or net investment hedge which is a hedge of the exposure to variability in cash flows that is attributable to a particular risk associated with all, or a component, of a recognised asset or liability; and could affect reported profit or loss.*

Further under IFRS 9, the change in the hedging instrument fair value is split into two components (see Figure 4): an effective and an ineffective part.

The effective part represents the portion that is offset by a change in fair value of the hedged item and is calculated as the lower of the following (in absolute amounts):

- The cumulative gain or loss on the hedging instrument from inception of the hedge; and
- The cumulative change in fair value (present value) of the hedged item (i.e., the present value of the cumulative change in the hedged expected future cash flows) from inception of the hedge.

The ineffective part represents the hedge ineffectiveness, or in other words, the portion of the change in fair value of the hedging instrument that has not been offset by a change in fair value of the hedged item. It is calculated as the difference between the cumulative change in fair value of the hedging instrument and its effective part. Common sources of ineffectiveness for a cash flow hedge are (i) the time value of the

[5] IASB ED/2010/13 Hedge Accounting, December 9, 2010, available at www.ifrs.org

[6] The **existing 2015 effective date of IFRS 9** has been deleted, and the IASB has left the effective date open until all the outstanding phases of IFRS 9 are finalised.

[7] When addressing hedging there are, in addition to IFRS 9, primarily three standards that have an impact on the way a hedge is structured: **IAS 21** *The Effects of Changes in Foreign Exchange Rates*, **IAS 32** *Financial Instruments: Disclosure and Presentation* and **IFRS 13** *Fair Value Measurement*.

[8] Accounting for derivatives – advance hedging under IFRS 9 by Juan Ramirez

option included in the hedging relationship, (ii) structured derivative features embedded in the hedging instrument, (iii) changes in timing of the highly probable forecast transaction, (iv) credit/debit valuation adjustments and (v) differences between the risk being hedged and the underlying of the hedging instrument.

FIGURE 2: *Relevant accounting standards for hedging*

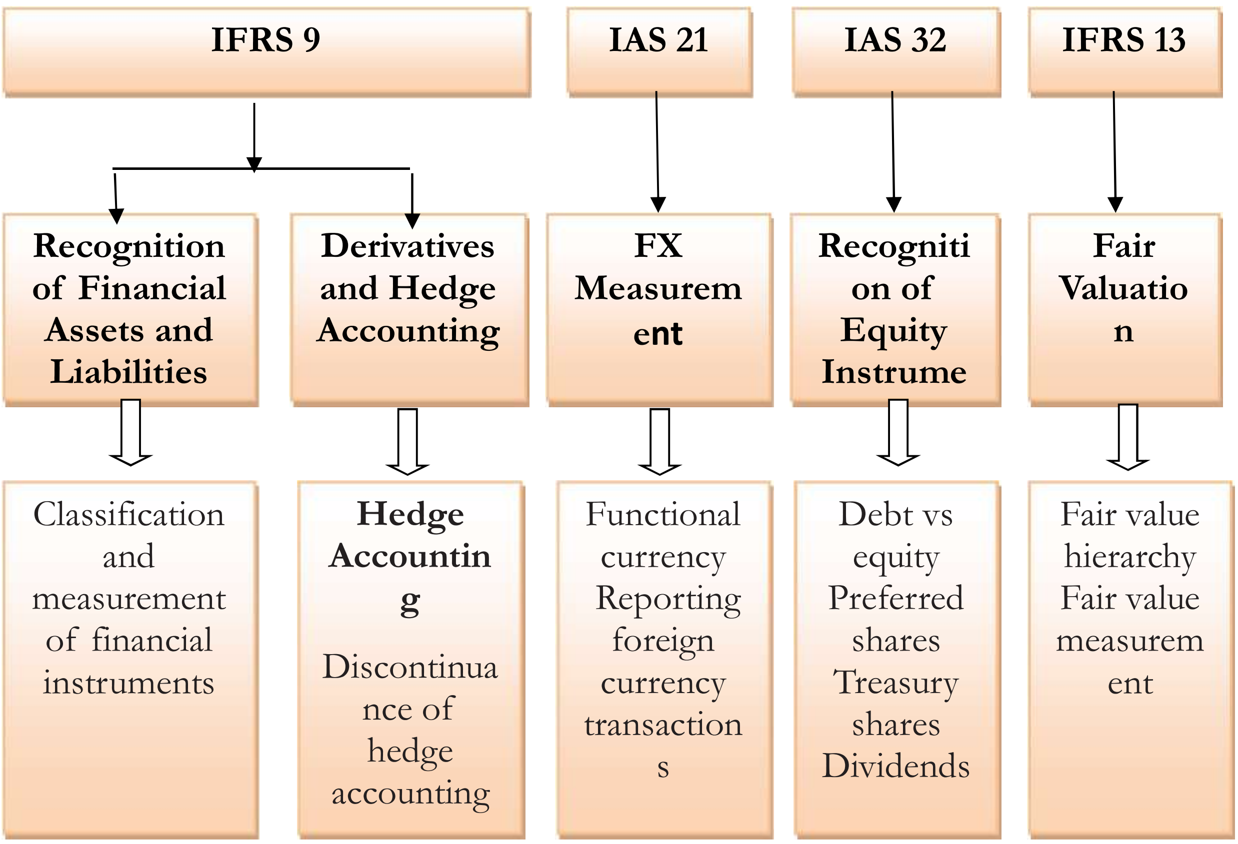
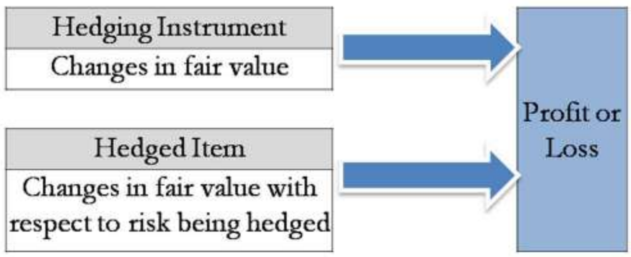


FIGURE 3: *Accounting for Fair Value hedges*



Accounting Recognition of the Effective and Ineffective Parts: The recognition of the change in fair value of the hedging instrument is as follows:

- The effective portion of the gain or loss on the hedging instrument is recognised directly in a separate reserve in OCI –the "cash flow hedge reserve".

- The ineffective portion of the fair value movement on the hedging instrument is recorded immediately in profit or loss.

2.3. Hedge effectiveness assessment:

2.3.1. *Qualifying criteria:* To qualify for hedge accounting, the hedging relationship must meet three requirements as set under IFRS standards such as eligible hedging instruments and eligible hedged items; formal designation and documentation of the hedging relationship and the entity's risk management objectives and meets all hedge effectiveness requirements.

2.3.2. *Assessment frequency:* Hedge effectiveness assessment is probably the most operationally challenging aspect of applying hedge accounting. At a minimum, whichever comes first, IFRS 9 requires that hedge effectiveness be evaluated:

- at the inception of the hedge;
- at each reporting date, including interim financial statements; and
- upon a significant change in the circumstances affecting the hedge effectiveness requirements.

Each effectiveness assessment relates to future expectations about hedge effectiveness and is therefore only forward-looking.

2.4. Assessment methods:

IFRS 9 does not specify a method for assessing whether an economic relationship exists between a hedging instrument and a hedged item. However, an entity shall use a method that captures the relevant characteristics of the hedging relationship, including its sources of hedge ineffectiveness.

The effectiveness requirement of an existence of an economic relationship between the hedged item and the hedging instrument (the "economic relationship requirement") is commonly assessed by applying either of Critical terms method[9]; Simple scenario analysis[10] method; linear regression method[11]; or Monte Carlo simulation method[12].

IFRS 9 requires an entity to specify at hedge inception, in the hedge documentation, the method it will apply to assess the hedge effectiveness requirements and to apply that method consistently during the life of the hedging relationship. The method chosen by the entity has to be applied consistently to all similar hedges unless different methods are explicitly justified.

4. HEDGING OF NYMEX WTI CRUDE OIL PRICE WITH A COLLAR OPTION

This section covers hedging of NYMEX WTI crude oil price with a collar option to protect the Oil & Gas producer from the variability in cash flow payments pertaining to a floating NYMEX WTI crude oil price. The hedge accounting treatment of derivatives is relatively clear from an IFRS 9 perspective as mentioned in previous section.

3.1 Zero-cost collar hedge execution:

In the present Crude oil market scenario, most of the oil and gas producers are looking to hedge their December 2015 crude oil production with a NYMEX WTI costless collar or "producer costless collar" such that the producers need to be hedged against December WTI prices trading below $45/BBL. As such, the producers are buying a $45/BBL December WTI APO (average price) put option for a premium of $2.10/BBL. In addition, in order to offset the cost of the $2.10 premium associated with the $45 put option, the producers are selling a $71 December WTI APO (average price) call option for a premium of $2.10/BBL.

As a result, the Oil and gas producers are entering into a collar with the following

[9] ***Critical terms method*** is a qualitative method (i.e., no numerical analysis is performed)
[10] ***Simple scenario analysis method*** is a quantitative method assessing how the hedging relationship would behave under various future scenarios.
[11] ***Linear regression method*** is quantitative method assessing, using historical information, how the hedging relationship would have behaved if it had been entered into in the past.
[12] ***Monte Carlo simulation method*** is a quantitative method assessing how the hedging relationship would behave under a large number of future scenarios.

terms to hedge their December 2015 crude oil production with a NYMEX WTI costless collar. The December WTI prices were expected to trade below $45/BBL.

Buying a $45 December WTI APO put option for a premium of $2.10/BBL.

Selling a $71 December WTI APO call option for a premium of $2.10/BBL in order to offset the cost of the $2.10 premium associated with the $45 put option.

When an option strategy as mentioned above is used in hedging crude oil price risk and hedge accounting is applied, IFRS 9 gives entities two choices:

1. To designate the option strategy in its entirety as the hedging instrument; which is rarely chosen; or

2. To separate the option strategy's intrinsic and time values, and to designate only the intrinsic value as the hedging instrument in the hedging relationship. The option strategy's time value is, therefore, excluded from the hedging relationship. This is the alternative commonly used because it enhances hedge effectiveness as the option's time value is not replicated in the hedged item. In other words, from a hedge accounting perspective the hedged item is assumed to lack any time value.

As a result, an oil and gas producer will designate the collar's intrinsic value (i.e., the intrinsic values of both the purchased and sold options) as the hedging instrument, and the highly expected variable NYMEX WTI crude oil price as the hedged item in a cash flow hedge of crude price risk.

3.2 Zero-cost collar hedge relationship documentation:

The producer shall document the hedging relationship as indicated in the Table 3.

Zero cost collar hedge effectiveness assessment

Hedge effectiveness of Zero Cost Collar strategy is assessed by comparing changes in the fair value of the hedging instrument to changes in the fair value of a hypothetical derivative13 only during those periods in which there is a change in intrinsic value. The terms of the hypothetical derivative are such that changes in its fair value exactly offset the changes in fair value of the hedged item for the risk being hedged. The main terms of the hypothetical derivative were as follows:

The change in the fair value of the effective part of the gain or loss on the hedging instrument (i.e., the collar's intrinsic value) is recognised in the cash flow hedge reserve of OCI in equity and the ineffective part of the gain or loss on the hedging instrument is recognised immediately in profit or loss.

The change in time value of the collar (the "actual time value") is excluded from the hedging relationship. Due to the absence of actual time value at the beginning and end of the hedging relationship, the changes in actual time value will be recognised temporarily in the time value reserve of OCI.

Hedge effectiveness is assessed prospectively at hedging relationship inception, on an ongoing basis at least upon each reporting date.

Firstly, for the hedging relationship to qualify for hedge accounting it is tested on various criteria under IFRS 9 for Hedge Effectiveness Assessment and Figure 5 below shows that the hedging relationship meets all the criteria to qualify for hedge accounting.

Secondly, the economic relationship between the hedged item and the hedging instrument is assessed on a quantitative basis using the Scenario Analysis method using two scenarios in which *NYMEX WTI crude oil prices* are shifted upwards and downwards by 20% and the changes in fair value of the hypothetical derivative and the hedging instrument are

[13] The hypothetical derivative is a ***theoretical NYMEX WTI crude oil price collar*** with no counterparty credit risk, with zero fair value at the start of the hedging relationship, a floor rate of 45 $/bbl and a cap rate of 71$/bbl such that the collar results in a zero-cost option combination.

calculated and compared to their initial fair values.

TABLE 3: *Hedging relationship documentation*

Risk management objective and strategy for undertaking the hedge	The objective of the hedge is to protect the variability of the cash flows due to unfavourable movements in the NYMEX WTI crude oil price below 45$/bbl. To achieve this objective while not paying any up-front premium for the hedge, the entity does not benefit from favourable movements in the NYMEX WTI crude oil price above 71 $/bbl. This hedging objective is consistent with oil and gas producer's overall risk management strategy of managing its exposure to NYMEX WTI crude oil price risk with focus on floor protection. Price risk. The designated risk being hedged is the risk of changes in the dollar value of the hedged cash flows due to movements in the NYMEX WTI crude oil price.
Type of hedge	Cash flow hedge
Hedged item	The cash flows stemming from the crude oil payments with reference to NYMEX WTI linked crude oil contract issued on 31 December 2015 with a 5-year term, for a 1.00 million bbl of crude oil notional, and a NYMEX WTI crude oil price.
Hedging instrument[14]	The intrinsic value of a zero-cost collar (the combination of a purchased floor and a sold cap). The main terms of the collar are a combination of: 1) Contract number 145668: a long $45 December WTI APO (average price) put option for a premium of $2.10/BBL for 1.00 million barrels for expiry on 31 December 2020. Because it is an exchange traded instrument, the credit risk associated with the instrument is considered to be very low. 2) Contract number 145669: a short $71 December WTI APO (average price) call option for a premium of $2.10/BBL in order to offset the cost of the $2.10 premium associated with the $45 put option. The counterparty to the collar is BP Singapore and the credit risk associated with this counterparty is considered to be very low i.e. "AA" rated or better. For the avoidance of doubt, the collar's time value is excluded from the hedging relationship.

[14] **Chicago Mercantile Exchange (CME)** - Crude Oil Options Contract Specs

***TABLE 4:** Hypothetical derivative terms*

Floor terms		Cap terms	
Start date	31 December 2015	Trade date	31 December 2015
Buyer	Oil and Gas producer	Buyer	Credit risk-free counterparty
Seller	Credit risk-free counterparty	Seller	Oil and Gas producer
Notional	1.00 million bbl of crude oil	Notional	1.00 million bbl of crude oil
Maturity	5 years (31 December 2020)	Maturity	5 years (31 December 2020)
Floor rate	45 $/bbl	Cap rate	72 $/bbl [15]
Underlying	*NYMEX WTI Contract*	Underlying	*NYMEX WTI Contract*

***FIGURE 5:** Effectiveness assessment results at inception*

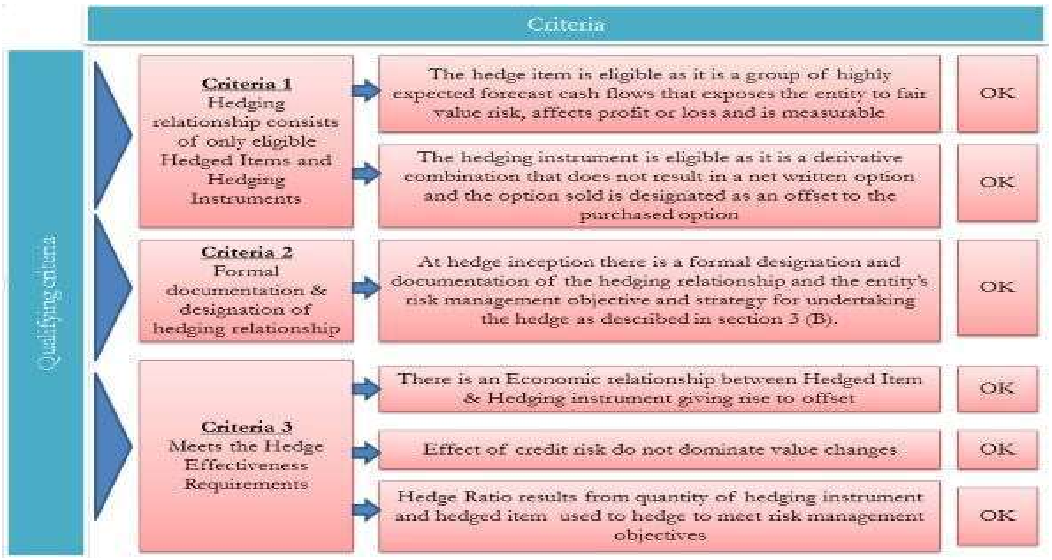
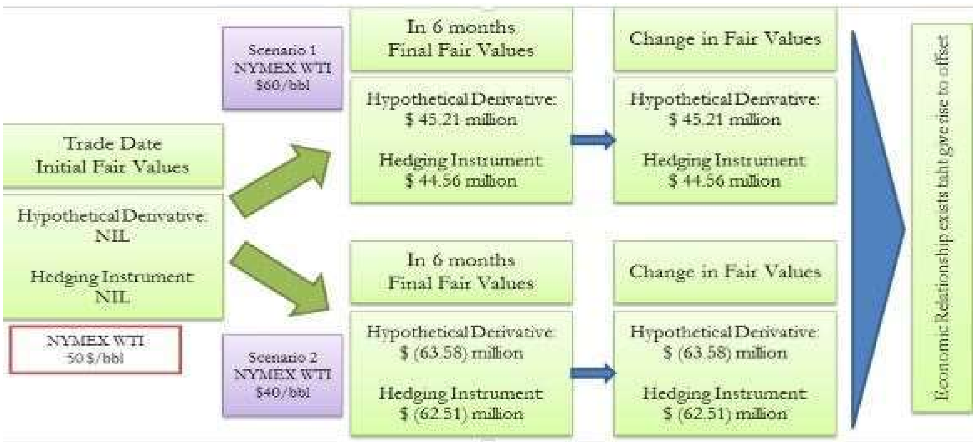


***FIGURE 6:** Scenario analysis assessment*



[15] The Cap rate of the hypothetical derivative (72$/bbl) is different from that of the hedging instrument (71$/bbl) due to the absence of CVA (**Credit Value Adjustment**) in the hypothetical derivative (the counterparty to the hypothetical derivative is assumed to be credit risk-free).

The cumulative change in fair value of the hedging instrument over that of the hypothetical derivative resulted in a degree of offset of 98.5% under Scenario1 and 102% under Scenario 2. Based on these results, it is concluded that an economic relationship existed between the hedged item and the hedging instrument.

3.4 Collar strategy's fair valuations, effective/ineffective amounts and cash flow calculations

3.4.1 Fair valuations of hedging instrument

IFRS 9 does not specify how to calculate the intrinsic value of cap (or a collar). The most accurate way is to calculate for each caplet/floorlet the present value of an undiscounted intrinsic amount by comparing the implied NYMEX WTI rate with the cap/floor rate. The sum of the discounted values yields the intrinsic value of the cap/floor. The time value of the collar was calculated as follows:

TABLE 5: *Collar fair valuation on 31 December 2015*

Date	**NYMEX WTI rate**	**Discount factor**	**Floor intrinsic value (undiscounted) *(1)*[16]**	**Cap intrinsic value (undiscounted) *(2)*[17]**	**Total intrinsic value (present value) *(3)*[18]**
31-Dec-2016	47 $	0.9685	-0-	-0-	-0-
31-Dec-2017	50 $	0.9667	-0-	-0-	-0-
31-Dec-2018	55 $	0.9299	-0-	-0-	-0-
31-Dec-2019	60 $	0.8904	-0-	-0-	-0-
31-Dec-2020	70 $	0.8507	-0-	-0-	-0-
CVA/DVA					-0-
Total intrinsic value					-0-
Collar Time value *(4)*[19]					-0-
Collar Fair value *(5)*[20]					-0-

TABLE 6: *Collar fair valuation on 31 December 2016*

Date	**NYMEX WTI rate**	**Discount factor**	**Floor intrinsic value (undiscounted) (1)**	**Cap intrinsic value (undiscounted) (2)**	**Total intrinsic value (present value) (3)**
31-Dec-2017	47$	0.9591	-0-	-0-	-0-
31-Dec-2018	45$	0.9146	-0-	-0-	-0-
31-Dec-2019	38$	0.8705	70,00,000	-0-	60,93,500
31-Dec-2020	40$	0.8275	50,00,000	-0-	41,37,500
CVA/DVA21					<4,000>
Total intrinsic value					102,27,000
Collar Time value (4)					62,51,000
Collar Fair value (5)22					164,78,000

[16] *(1)* 1 mn bbl × max (NYMEX WTI rate – 45$/bbl

[17] *(2)* <1 mn bbl> × max(71$/bbl - NYMEX WTI rate; 0)

[18] *(3)* (Undiscounted cap intrinsic value + Undiscounted floor intrinsic value) × Discount factor

[19] (4) Collar time value = Collar total fair value – Collar intrinsic value

[20] *(5)* Initial fair value was nil, calculated using the Black–Scholes model

[21] CVA = {Credit Risk – free settlement amount} * Probability of Default (PD) * Loss Given default (LGD)

[22] Fair value calculated using the Black–Scholes model

The following table summarises the split between the collar's intrinsic and time value at each reporting date:

TABLE 7: *Collar's intrinsic and time value at each reporting date*

Date	Collar intrinsic value	Collar time value	Collar total fair value	Period change in intrinsic value	Period change in time value	Period change in total fair value
31-Dec-2015	-0-	-0-	-0-	—	—	—
31-Dec-2016	102,27,000	62,51,000	164,78,000	102,27,000	62,51,000	164,78,000
31-Dec-2017	91,30,000	53,00,000	144,30,000	<10,97,000>	<9,51,000>	<20,48,000>
31-Dec-2018	-0-	11,70,000	11,70,000	<91,30,000>	<41,30,000>	<132,60,000>
31-Dec-2019	-0-	1,20,000	1,20,000	-0-	<10,50,000>	<10,50,000>
31-Dec-2020	-0-	-0-	-0-	-0-	<120,000>	<120,000>

3.5 Effective and ineffective amounts:

The following table summarises the fair value cumulative changes of the hedging instrument (i.e., the collar's intrinsic value) and the hypothetical derivative (which had intrinsic value only):

TABLE 8: *Intrinsic value of hedging instrument and the hypothetical derivative*

Date	Hedging Instrument fair value	Cumulative change	Hypothetical derivative fair value	Cumulative change
31-Dec-2015	-0-	—	-0-	—
31-Dec-2016	102,27,000	102,27,000	92,27,000	92,27,000
31-Dec-2017	91,30,000	91,30,000	91,00,000	91,00,000
31-Dec-2018	-0-	-0-	-0-	-0-
31-Dec-2019	-0-	-0-	-0-	-0-
31-Dec-2020	-0-	-0-	-0-	-0-

The ineffective part of the change in fair value of the hedging instrument was the excess of its cumulative change in fair value over that of the hypothetical derivative.

TABLE 9: *Effective part & Ineffective part of the hedging instrument*

Date	31-Dec-16	31-Dec-17	31-Dec-18	31-Dec-19	31-Dec-20
Cumulative change in fair value of hedging instrument	102,27,000	91,30,000	0	0	0
Cumulative change in fair value of hypothetical derivative	92,27,000	91,00,000	0	0	0
Lower amount	92,27,000	91,00,000	0	0	0
Previous cumulative effective amount	-	92,27,000	91,00,000	0	0
Available amount	92,27,000	<127,000>	<91,00,000>	0	0
Period change in fair value of hedging instrument	102,27,000	<10,97,000>	<91,30,000>	0	0
Effective part	92,27,000	<127,000>	<91,00,000>	0	0
Ineffective part	10,00,000	<9,70,000>	<30,000>	0	0

3.6 Time Value Reserve Amounts:

Under IFRS 9, when the time value component of an option is excluded from the hedging relationship, its cumulative change in fair value from the date of designation of the hedging instrument is temporarily accumulated in OCI to the extent that it relates to the hedged item.

In our case, due to the absence of actual time value at the beginning (31 December 2015) and end (31 December 2020) of the hedging relationship, changes in actual time value were recognised temporarily in the time value reserve of OCI, as shown in the table below. No reclassification to profit or loss was carried out during the term of the hedging relationship as the carrying value of the time value reserve in OCI was expected to be nil at the end of the hedging relationship.

TABLE 10: *Amounts to be recognised in the time value reserve of OCI (in $)*

	31-Dec-16	31-Dec-17	31-Dec-18	31-Dec-19	31-Dec-20
New entry in reserve	62,51,000	<9,51,000	<41,30,000>	<10,50,000>	<120,000>
Reserve carrying value	62,51,000	53,00,000	11,70,000	120,000	0

5. FINAL REMARKS

As may be observed from hedge effectiveness assessment of zero cost collar strategy, the collar had no intrinsic value at the start of the hedging relationship because both the cap rate (71 $/bbl) and the floor rate (45 $/bbl) were well “away” from the projected NYMEX WTI rates. The accounting for the time value of a collar that has a zero time value both at the start and end of the hedging relationship is relatively simple, as all the changes in time value are recognised in the time value reserve of OCI and no reclassification is needed.

A non-zero intrinsic value at the start of a hedging relationship has important operational implications since the entities would need to keep track of the intrinsic and time values of each caplet/floorlet and compare them with the intrinsic and time values to the corresponding caplet/floorlet of the hypothetical derivative. As a result, effective/ineffective amounts have to be separately calculated for each caplet/floorlet combination, which is a complex exercise.

Oil & Gas producers, Traders and portfolio managers judge the effectiveness of their hedge strategies in terms of volatility reduction. In order to minimize the operational burden of hedge accounting, management therefore should consider the methods or tools used for risk management purposes and evaluate which methods are appropriate for hedge effectiveness assessment. Such an approach would be in line with the objective of the new hedge accounting requirements, as described in IFRS 9. The aim is to better reflect the effect of the entity's risk management activities in the financial statements. This might include Value at Risk calculations, volatility reduction methods or other approaches such as Monte Carlo simulation for testing the hedge effectiveness, which shall be the future scope of this research paper.

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ISIS AND ITS IMPLICATIONS ON ENERGY SECURITY

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KEYWORDS

ISIS, energy, market, infrastructure, external powers, energy security, nexus, prospect

Abstract: The Islamic State of Iraq and Syria (ISIS) or Islamic State (IS) militants have captured significant oil and gas fields in Iraq and Syria and developed their independent financial mechanisms to recruit cadres, carry operations and run caliphate administration in their occupied territories. The IS-controlled oil fields in Iraq and Syria produce 25,000 to 40,000 barrels of oil per day, which is about $ 1. 2 million. They earn money at earliest, demands protection money and transit fees and sells oil in the local and international black market with cheap rates. Thus, the cheap oil and energy market has turned as a source of income for the poor or displaced Iraqis and Syrians. In the national and international market, they have buyers, traders, businessmen and middle man who support and assist this black marketing. Apart from domestic black market, the oil is being smuggled out to Iran, Kurdistan, Turkey, Syria and other countries as well. As a consequence, there has been reduction in oil production, loss of revenues and disinterest of foreign companies to invest in the regions. The external forces such as US and Russia and their air strikes and ground operations have disrupted makeshift refineries, pipelines and transport convoys of IS to deliver oil to the black market. However, since there is no large scale ground operations by the external powers, most of the oil wells and refinery are under the IS control, and 'nexus' between government and militia have troubled the operations against IS and their oil trade. The paper will anyalse the mechanisms through which ISIS carries out its oil market, ISIS and its adverse impact on energy market and infrastructure in Iraq and Syria, Implications of energy market, intricacies or nexus in black market, outcomes of armed operation by external powers such as Russia and coalition forces with specific reference to United States.

1. INTRODUCTION

The Islamic State of Iraq and Syria (ISIS) or Islamic State (IS), a terrorist organization and transnational criminal group, seeks for a caliphate comprising a vast stretch of territories and countries through the means of selling of oil, ransom, looting and black marketing. On October 30, 2014, the U.S. Treasury Under Secretary for Terrorism and Financial Intelligence David Cohen noted that the Islamic State has "amassed wealth at an unprecedented pace," including receiving at least $20 million in ransom payoffs since January 2014 (The Jamestown Foundation, 2015), $675 million from looting of banks and $145 million in oil sells, plundering everything starting from antiquities to private property, protection money, demanding 5% to 20% taxes on salaries, plus fees for a range of economic activities, as revealed by US officials (Lakshmanan, 2015).

Although IS receives donations, especially from Gulf-based financiers, yet, they are relatively insignificant contributor to its coffers (www.economist.com). Instead, recently, the bulk of its money comes from oil revenues from fields under its control or stealing from the oil fields in western Iraq and eastern Syria. Ben Van Heuvelen, the managing editor of Iraq Oil Report, recounts, "ISIS was stealing oil out of pipelines and storage tanks, loading it onto trucks and selling it to drivers. With $2 million in daily revenue from black market oil, the Islamic State insurgency not only holds sway over swathes of Syria and Iraq but has also begun to lay the foundations to become a - a proto-state of small petro-state (Pizzi, 2014). The Islamic State shortly after the fall of Mosul revealed that the group had assets worth of $875 million, which increased to an estimated $2 billion dollars, susequently. The 11 oil fields that the IS controls in Iraq and Syria have made it financially stable organisation. The oil fields occupied by IS produce between 30,000 to 45,000 barrels of oil per day, which is worth of $2 million. This shows the significant share of oil in the total earnings of $3 million per day (Dalby, 2014).

The regional energy picture in areas, controlled by the Islamic State and surrounding regions in Syria and Iraq, is a complex phenomenon since energy infrastructure cuts across territories controlled by different groups such as IS, Kurds, rebels and the government. Nonetheless, some trends are clear: the UK risk management firm Maplecroft revealed, the Islamic State has controlled six out of Syria's ten oil fields, including the large Omar facility and main oil fields in Deir Az-Zor province; and in Iraq, at least four small fields, including those at Ajeel (near Tikrit city), Kaz (Anbar province) and Hamreen have been captured, and the group sold up to 80,000 barrels of oil a day worth several million dollars through the regional black market (Financial Times, 2014 and Bodissey, 2015).

Yet, the IS don't have refineries to refine crude and for them refined crude is more important than the unrefined. Hence, the ISIS wants to become energy independent and achieve self-funded statehood, a plausible goal if it is cut off from neighbors and establish its own borders (Feldman, 2015). Although the make-shift refineries such as Chinese, Turkish, and mini refineries that use primitive distillation and heating methods have limitations of processing such as 500-1,000 bpd yet, they are looking for state-run refineries like Baiji (Iraq), which is a part of its grand strategy to become a functioning state.

2. HOW AND WHERE THE MONEY IS SPENT

The lack of expertise in extracting and refining oil is a major concern for the IS militants. However, it manages the situation by hiring technicians and experts. The ISIS pays fighters around $400 a month, which is more than Syrian rebel groups or the Iraqi government offer. It appears to have no trouble in purchasing weaponry, either on the black market or from corrupt officials or militias. The militants run services, not always successfully, across the areas it controls, in the form of paying to schoolteachers, school fees, and financial assistance to poor under national service, and protection of the people in its occupied territories (www.economist.com).

The group is controlling over the oil resources to strengthen its ties with the local tribes and allowing some Bedouin tribes such as the Bar al Milh, al Kharata, Amra, Okash, Wadi Jureib, Safeeh, Fahda in Deir al-Zor province and many other medium and small disused wells in the Jebel Bushra area, to tap wells the IS controls. Moreover, the influential Jabour tribe, whose kin spread across the borders of Iraq has been benefited through the illegal oil trade market. Assisted by the tribals, the traders, largely supportive of ISIS, have continued to build stockpiles, selling oil and even smuggling into government-held areas in Syria (Al-Khalidi, 2014).

Following a series of accidents in the oil wells and installations, owned by IS in Iraq and Syria, the group advertises for skilled technicians to manage the facilities it has captured. For instance, it has offered $225,000 a year for a manager to run their refineries, the most senior of several vacancies that the Islamic State organization is seeking to fill. The recruiting call has gone out via jihadist networks as far to North Africa. The black market agents in Iraq's northern Kurdish region have also been quietly advertising the vacancies. Robin Mills of Manaar Energy, a consultancy firm in Dubai said, "They are trying to recruit skilled professionals who are Ideologically suitable. (www.economicpolicyjournal.com)

More to say, in Kurdish-held territory, there are some government staff who still get their salaries from the Syrian government.

3. MODUS OPERANDI

Although the oil grey marketing is prominent today in the Middle East region today, yet, Valerie Marcel, a Middle East and Africa energy specialist at Chatham House, reveals about the root of illegal oil market, "The fact that Iraq was under sanctions, which led Kurdish and Iraqi businessmen to fill a vacuum and create smuggling networks for Iraqi oil. Likewise, Iranian and Syrian networks have grown because of decades of bans on exports (www.economicpolicyjournal.com).

Turkey has been major conduit for illegal oil exports since the days of Saddam Hussein. These smuggling rings are still very active, and are now working with IS and contributing to its exploding wealth (Dalby, 2014). Though the details of the group's oil smuggling operations are murky, the ISIS and its Sunni allies are known to have dominion over extensive smuggling routes, which even touches far away countries such as Afghanistan and Armenia. There are reports that, the crude is transported by tankers to Turkey via Mosul, to Jordan via Anbar province, to Iran via Kurdistan, to the Kurdistan region of Iraq and to Syria's local market, where most of the crude gets refined. The cut-rate price for the crude is $18-25, refined oil range from $50-$60 per barrel, nearly three times the price of the crude and a liter of gasoline sells for half a dollar. Yet, low price is profitable since the loss occurred through selling is compensated through large-scale selling since there are many buyers to purchase who would sell them at higher price in the black market (Dalby, 2014). Commenting on black marketing, Ben Van Heuvelen, managing editor of Iraq Oil Report says, "IS was stealing oil out of pipelines, out of storage tanks, loading it onto trucks and selling it to drivers for very cheap." The cut-rate price of $25 a barrel was an incentive for traders to buy--The drivers were then selling to middlemen, then middlemen would find a way to launder the oil, so to speak, and then sell it on." (www.npr.org, 2014). More to mention, According to Samir Aita, a Syrian economist, "Parties that are fighting each other still exchange services and find bargains." The Oil traders says, that after taking control of oil wells from the rivals, the ISIS has continued the practice of guarding some pipelines, which are transporting crude of Kurds in their fields in northeast Syria to a government-run refinery in Homs in exchange for protection money. They would take fees and transit fees so the oil would go through without blowing up pipelines (Al-Khalidi, 2014).

The local businessmen have continued to send convoys, sometimes up to 40 trucks, carrying oil from Islamic State-run wells through insurgent-held parts of Syria even during day time and pass more quickly through its occupied checkpoints. It has encouraged the customers to stockpile and load up as much as possible, offered discounts and deferred payments to supply more oil. The plants have been constructed by private businesses at a cost of around $150,000 to $250,000 and processed 150-300 bpd of Islamic State-supplied crude oil. While some local businessmen have made large profits from the illicit oil trade, many other civilians have come to depend on the informal market which sprung up since the start of Syria's conflict. The Americans know that these wells and oil market have opened an opportunity for many Syrians to benefit who even don't have links to militants. Those who buy this fuel are only the poor who use it to make bread and cook their daily meals to feed their families (Al-Khalidi, 2014).

4. IS THERE ENERGY INSECURITY?

Since the outbreak of militancy, many wells have been shut down and foreign firms withdrawn shares, equipment looted and warehouses emptied. Besides, national industries and multinational companies like Royal Dutch Shell and Petro Canada have stopped their production and abandoned the conflict zones; thus, making full use of natural resources a real challenge in both the war-ravaged countries. But, the old certainty that oil prices respond sharply to geopolitical upset is no longer seems the case. It's a change that reflects a new global market where the rise of U.S. shale fields and Saudi Arabia's determination to defend the country's share of world production ensures ample supply. The Saudi Arabia's decision to pump more than 10 million barrels a day as it tries to grab market share from US Shale has caused more flow of crude oil and gas resources in the global energy market. Iraq has been able to boost production to its highest since 1979, approaching 4 million barrels a day, adding 600,000 barrels day in extra output over the last two years. In Libya, production has fluctuated wildly over the last two years even as militias fight. It is remarkable that when there was the rise of ISIS, hardly any geopolitics of oil price affected the region. In the opinion of oil industry historian Daniel Yergin, "Despite all the tensions in the Middle East, there is little risk premium in oil right now---- and if there is a disruption, supplies can be made up elsewhere" (www.bloomberg.com, 2015).

In Iraq, there is a risk that ISIS and other militant groups could gradually expand operations and begin targeting key energy infrastructure in the south. The IS militants had captured Baiji, a key northern city containing Iraq's largest oil refinery, for a short period (www.eiu.com, 2014), and the fall of Ramadi to ISIS, raised serious question about Iraq's national security. But, oil production in Iraq is situated far south of Ramadi, around Basra on the Persian Gulf, and these massive oil fields are not in any immediate danger. Despite the onslaught of IS, Iraq has scaled up oil output over the last years. From 2013 to 2014, production climbed from 2.9 to 3.1 million barrels per day and it is expected to see its oil exports surge by 700,000 barrels per day in 2015, putting its overall export level at 3.75 million barrels per day (Cunningham, 2015).

Contrast to Iraq, Syria's production has decreased from an average of 28,000 barrels per day (bpd) in 2013, from 164,000 bpd in 2012. Oil sells made up nearly a quarter of state revenues before the war broke out and the oil industry had been key to the Syrian economy, with a daily output of about 380,000 barrels, until fighting began three years ago (www.theoilandgasyear.com, 2015). The Syrian government has revealed that it has lost $3.8 billion in stolen oil because of the militancy. Towards the end of August 2015, as reported by Reuters and UK-based NGO the Syrian Observatory for Human Rights, Islamic State militants have seized the Jazal oilfield, the Syrian regime's last crucial oilfield. More to mention, half of Syria's estimated pre-war production is located in Hasaka province, which the Kurds have taken control, and if the province falls to Islamic State, the IS will have control over the major oil lifelines of Syria.

5. GOVERNMENT-MILITIA NEXUS IN SYRIA!

There are instances where tacit arrangements have been made between the ISIS militants and local state officials to ensure that basic necessities and services such as electricity and water are not disrupted or destroyed. Traders and middle men with connections on both sides of the war have sought to make a big margin of profit by reselling fuel in government areas as well such as Latakia region, a hub of pro-Assad region. Crude buyers, directly or indirectly, include businessmen close to Assad's ruling circle. "It seems that trade is going through brokers," says Joshua Landis, director of the Center for Middle East Studies at Oklahoma University. (www.pri.org/stories/).

Western trade sanctions block imports of fuel from Syria. Landis says that has made the Assad regime reliant on oil that's either smuggled outside the country or pumped inside Syria itself — which means doing trade with the ISIS. There are accusation and some justifications that, the Assad government in order to run his war machine and cities, needs energy to which the ISIS "cheaply" supplies since it controls much of the country's oil fields. The ISIS also goes for oil trade, primarily for cash to run administration. Danny Glazer, the Assistant Secretary at the U.S. Treasury Department, says, in the BBC2 documentary, "The Assad regime needs the oil and the world's richest terror army needs the cash; hence they are willing partners to do business even as they're fighting each other." (www.ibtimes.com).

6. WHY SMUGGLING ACROSS KURDISTAN?

After Mosul fell to ISIS, troops belonging to the Kurdistan Regional Government (KRG) claimed to have taken control of Kirkuk when government forces fled the northern oil city. Yet, the heightened insecurity in the north is a risk to Kurdish exports by truck and pipeline. Moreover, Influx of hundreds of thousands of refugees into Kurdistan and low oil price has created an environment where oil consumption increases and black market proliferates. On the other way, the heightened insecurity in the north is a risk to Kurdish exports by truck and pipeline (www.eiu.com, 2014). The British-Turkish firm Genel Energy, which has a 45 percent stake in the Taq Taq oil field in Kurdistan Regional Government (KRG) region, is working together with the Nokan Group, which is accused of supplying ISIS oil through the Kurdish territory. When confronted on Genel's position on working with institutions allegedly involved in transporting ISIS oil, Andrew Benbow, spokesperson for the Anglo-Turkish company, said: "These are all questions to be asked to the KRG rather than ourselves" (Ahmed, 2015).

7. KRG-TURKEY-IRAQ NEXUS!

At the juncture of crackdown on Kurdish oil exports to ISIS in Iraq and KRG, the energy minister Hussein al-Shahrestani of Iraq got succeeded with Abdul-Mehdi. But, Abdul-Mehdi has been accused of having much conciliatory approach to the Kurdish oil question that happens to suit the interest of western investors in the KRG. To counter KRG allegations of black marketing in Iraq, the ruling Islamic Dawa Party, developed "significant intelligence inputs which confirmed that elements of the KRG had tacitly condoned IS oil sells on the black market" (Ahmed, 2015). On the other side of the picture, the KRG and Turkish authorities vehemently deny any role in facilitating ISIS oil sells. But, Turkey's support for Islamist rebels, who opposed to Bashir al-Assad's government in Syria, turned pivotal for the rise of ISIS, and today the country has turned a blind eye to the groups illicit tankers, makeshift pipelines and smuggling routes. The recent satellite image of Russia is an indicative of Turkey's silence over illegal cross border illegal trade of crude and refined oil. Not to deny, the Turkish effort such as tightening of its border and support to US in its operation against the ISIS is too little and too late. At the same time, both the governments of Turkey and KRG have taken measures to crackdown smuggling operations such as arrest of Kurdish "middlemen" involved in the ISIS black market; yet, the evidences continues to emerge that these measures are largely piecemeal, and have failed to address deep rooted corruption at the highest levels. And the recent military coup in Turkey, growing differences between Washington and Ankara on President Erdogen's crack down approach has adversely effected coalition fight against IS in Syria and Iraq.

8. AIRSTRIKES AND IMPLICATION FOR ENERGY MARKET

Since the ISIS is able to pay for everything it needs, the group cannot be defeated without cutting off its funds. Therefore, the coalition forces aims at attacking the sources of its revenue as well as stopping the group from advancing militarily. America and its allies have carried out air strikes on ISIS-controlled oil refineries in Syria and Iraq. America and Britain have approached the countries to stop paying ransoms for hostages, and imposition of sanctions against ISIS leaders. However, the siege of Ramadi by ISIS and retreat of Iraqi forces, despite US air support, turned a major setback for US and Iraq (Cunningham, 2015). However, the American airstrikes can destroy the black market of oil trade and cut important source of income for ISIS. Joshua Landis, the director of the Center for Middle East Studies at Oklahoma University says, "The US can bomb IS tankers, can bomb the oil wells, can easily take out the oil, this would be very easy. But, America doesn't want to destroy the oil infrastructures since it will cause a lot of hardship to the civilian population--- I'm sure America is not there yet" (www.pri.org/stories/). So far, the US has conducted 8,605 air strikes, and more than 95 percent of all coalition strikes is launched by the US. Before striking the convoy of oil tankers or trucks of IS, the US fighter jets drop the leaflets, warning, 'Hey, run away, we're about to strike your trucks'. Likewise, Russian forces in Syria have continued to hit terrorists' targets, conducting from 33 to 88 sorties per day and strikes have been conducted in the provinces of Raqqah, Hama, Aleppo, Latakia, Idlib, Homs and Deir ez-Zor. Since the start of the operation, Russian air raids have destroyed more than 380 sites of IS, which includes 32 oil complexes, 15 refineries, 23 oil pumping stations and 1,080 oil-hauling trucks. Moreover, both the coalition and Russian forces have naval forces to back air strikes. In the Mediterranean Sea, the US has stationed 4 naval warships, Russia, 1 and France, 1 aircraft career. Likewise in the Caspian Sea, Russia has stationed 4 warships. However, all the forces have left the oil wells untouched, so as to avoid destruction of energy infrastructure and public sufferings.

9. PROSPECT OF ENERGY SECURITY

Eliminating ISIS and restoring oil market stable in Syria and Iraq is a challenging task to all the stake holders of war. Steps have been taken, yet, some crucial points need to be addressed to make the operations a successful one. The future of war, and important strategies of war may include:

Firstly, Keep the ISIS deprived from getting oil fields, starve it of revenue, block it from the maritime connectivity, which is accessible from countries like Syria and Lebanon.

Secondly, Turkey and Syria should show their sincere commitment to stop oil black marketing across their border regions.

Thirdly, the United States must put pressure on its coalition partners in the Middle East to take tough measures against oil black marketing with the ISIS.

Fourthly, inside the countries of Iraq and Syria, shutting down of illicit oil trade requires an entire security arrangement, structure and strategy which will be resistant to corruption. However, this may take a bit longer period.

Fifthly, the oil wells and infrastructures must not be targeted, since it would lead to backlash of the local communities and destruction of energy infrastructure.

Sixthly, the mere air strikes is not suffice to destroy the entire structure and operation of ISIS; most important problem in this operation is to get information from the hostile territory. Therefore, along with air strike, ground operation, based on concrete and sufficient information, could help both the national and foreign powers fight against ISIS more effectively.

Seventhly, although the Islamic State has stolen hundreds of millions of currencies from banks and other institutes, cash eventually runs out and today they find it harder to sell antiquities on the black market due to tightening measures by the countries concern.

Eighthly, the United Nations Security Council Resolution related to trade in oil and refined oil products, modular refineries and related materials, besides items of cultural (including antiquities), scientific and religious importance, needs to be implemented sincerely without delay.

Ninthly, although the truck convoys face the wrath of airstrikes, and tankers confiscated by the Iraqi and Syrian forces, yet, there are many open roads and alternative routes to carry oil.

Tenthly, destruction of refineries and targeting of oil trade have adversely affected the small traders and local people who even not inclined to ISIS ideology. The war has turned their family life miserable and destruction of livelihood. Therefore, along with operations against IS, the civilian concerns needs to be taken into account.

Eleventh, even with the elimination or check of IS, the oil market is not going to change significantly because of deep- rooted corruption in the region and conflicting interests of all the stake holders.

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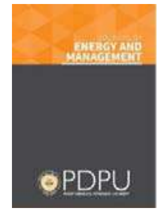

BOOK REVIEW

Achieving Universal Energy Access in India: Challenges and the Way Forward.

ISBN : 978-93-515-0137-4

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India is still struggling with the problem of providing access to energy services even after 68 years of Independence. India's population of more than 1028 million is growing at an annual rate of 1.58%. As fossil fuel energy becomes scarcer, India will face energy shortages significantly due to increase in energy prices and energy insecurity within the next few decades (Kumar et al., 2010). In the book "Achieving Universal Energy Access in India: challenges and way forward ", the authors PC Maithani and Deepak Gupta have done a remarkable job in directing our attention to energy access issues in India. Both personnel having served the Ministry of New and Renewable Energy, were instrumental in launching of India's ambitious National Solar Mission. Both of them drew on their long tenure of experiences in the government to this book.

This is a well-documented book of about 250 pages with lots of informative charts and tables, but the flow goes well because of the authors' narrative skill. There are 10 chapters in this book and each chapter is a full academic research note seeking to advance a discussion for formulating a new policy perspective on promoting renewable energy. The initial three chapters addresses sophisticated topics related to energy economics, which Maithani-Gupta presents these clearly and without oversimplifying the fact that energy and economic growth are strongly related. Energy access becomes a critical component not only to reduce rural poverty and drudgery, but also is one of fundamental condition for holistic rural development. Most of all, it succeeds in helping readers understand the breadth and complexity of the world of energy.

In the next chapter (4), the authors provide understandable descriptions of the constantly evolving policies and government initiatives/programmes (within the period 1974 to 2005) to promote rural electrification projects all over the country. The focus of this chapter is to bring to light the problems faced in India in terms of energy consumption as well as the hindrances faced by rural electrification networks. The author discusses in this chapter the key aspects of electricity access, status of access in India, the challenges faced in rural electrification and the potential of renewable energy.

The next two chapters (5 & 6), the author highlights the fact that more than 44 percent of the household in rural India lack basic access to electricity. Even those villages that have been provided with grid power receive less than 6 hours supply in most cases. Such a situation exists despite several initiatives and policies adopted by the government to support poor households. Maithani-Gupta indicated that renewable energy technologies could provide a solution to these problems, citing examples of successful programmes, models and government initiatives implemented in the past.

The link with power and lack of energy access comes even more sharply in the next chapters (7 & 8) on cooking fuels. The problem is equally acute with regard to cooking energy. According to census of 2011, over 85 per cent of household in rural India is still dependent on biomass to meet its cooking needs. Although biomass resource is available in abundant, the health hazards associated and the resultant smoke appears to override the free factor consideration. The authors have also stressed upon the contentious issue of subsidies for the use of LPG as a cooking fuel. The concluding chapters discusses about several long-term strategies, decentralized administration and a commercialized subsidy program for rural energy development, that would be required to integrate developmental efforts suggested by the authors in future policy formulation, so as to resolve the energy access problem in India.

India is at an energy crossroads, with policy formulations and decisions to make, to improvise the infrastructure for energy access in rural areas. Improving energy services for poor households in developing countries remains one of the most pressing challenges facing the development community. A high concentration of population without access to energy is still found in India, where the largest number of people in any country in the world without adequate energy access lives (Bhattacharyya, 2006). The government should redesign energy programs, keeping in mind the energy future of rural India. The government also needs to efficiently incentivize such energy programs to make them sustainable in a long run. From a policy perspective, the book is a gem as it the documentation extensively presents some holistic facts about electricity and cooking energy access in India. The book takes a critical look at the present energy policy and addresses ways to improve energy penetration. In doing so it encourages the use of renewable energy as an alternate medium, challenging the traditional power proponents.

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