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Marginal Gas Field Development in Nigeria: Challenges and Prospects

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Abstract: Most marginal gas fields in Nigeria lie fallow due to challenges such as lack of funding, subsurface risks and uncertainties, crude oil price instability, social, political, environmental and technical issues which have hampered successful development of these fields into profitable ventures. In order to surmount these challenges and ensure marginal gas field operators produce at higher capacities, there is need to seek out of the box solutions that will position these operators in advantaged positions resulting in increased productivity, translating to overall economic growth and development. One of such solutions is the development of a template that is economically and technologically suited for marginal gas field development in Nigeria. Therefore, this study highlights critical segments of field development plan for marginal operators such as commercial, technical, data analysis, organizational and legal and regulatory framework. In addition, the study proffers solutions to challenges faced in developing an optimum marginal gas field development. Furthermore, the study proposes that if template proposed is used as a baseline for marginal gas field development in Nigeria, the needed increase in gas production from marginal gas fields and its antecedent multiplier effect on the economy would soon be evident. Finally, the study recommends that optimization studies should be carried out on marginal gas field development plan using field data so as to develop an optimum field development template for marginal field operators.

Key words: Natural gas · Marginal field · Field development · Challenges · Operators · Template

INTRODUCTION

Nigeria as a nation boasts proven gas reserves of 188.8 Trillion Cubic Feet (TCF) [1]. Hence, the country can be regarded as a key player in global natural gas market with strong propensity to be a major gas exporter. There are several efforts by both Federal Government (here after FG) and oil and gas companies to commercialise natural gas resources so as to increase Nigeria's natural gas exporting capacity. Policies such as Nigerian Gas Master Plan (NGMP) and Nigerian Gas Flare Commercialisation Programme (NGFCP) have been proposed in order to monetise the nation's natural gas resources. In spite of these efforts, some gas fields still remain unproductive even though over 183 of these marginal fields have been put at an estimated 2.3 billion barrels of stock tank oil initially in place [2].

This necessitated the FG to launch the Marginal Field Programme in 2001, a programme in which indigenous companies where invited to bid for 24 out of 116 gas fields [3]. This was done to increase the country's daily crude oil production from 2.4 million barrels/day to 4.0 million barrels/day which would result in corresponding increase in crude oil reserves (to over 40 billion barrels [4]) and gas reserves & production; with a resultant increase in foreign exchange earnings. Hence, 24 marginal fields were awarded to 31 companies to develop and commercialise as the hope at that time of allocation was that these fields will be monetized for the nation's economic growth and development. Unfortunately, this has not translated to improved gas production as oil production from these marginal oil fields in 2014 was 2.46 % of total crude oil production in Nigeria [5]. This is as a result of challenges faced by marginal field operators such as lack of funding, subsurface risks and uncertainties, crude oil price instability, social, political, environmental and technical issues [6] that hamper successful development of these fields into profitable ventures.

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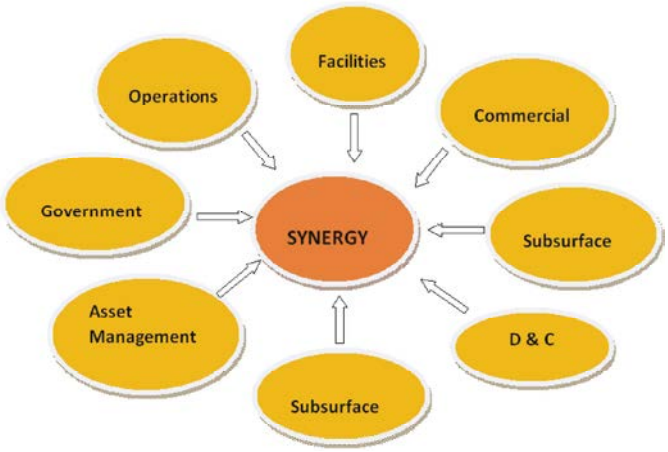

Fig. 1: Gas Field Development Plan Team (modified from [23])

Hence, there is need to seek out of the box solutions for these operators in order to position them in advantaged positions for improved gas production, translating to overall economic growth and development. One of such solutions is the development of a template that is economically and technologically suited for marginal gas field development in Nigeria. Therefore, this study focuses on the development for improved gas production by marginal gas fields operators in Nigeria.

Gas Field Development: Field development planning entails the steps involved in identifying concepts technically achievable in the development of a field to its best performance [7]. It is a process that seeks to exploit hydrocarbon resources in the most economic and profitable means possible. In addition, gas field development is a multidisciplinary operation carried out in collaboration between different teams/departments such as Facilities, Commercial, Operations, Government, D & C, Subsurface and Asset team as shown in Fig. 1. It involves systematically planning how the reservoir fluid will be produced from the gas reservoir and transported to the end user in a cost effective and profitable manner. It is one of the most important activities that determine the success of any gas field project from exploration to production and transportation. Therefore, it is imperative for marginal field operators in Nigeria to devise a systematic and purpose specific gas field development plan that would be cost effective and efficient for exploration, production and transportation of their assets. Furthermore, literature review on the subject revealed that different authors have done works on both marginal and non-marginal gas fields. As such, some of these works will be reviewed in this section in chronological order.

Critical literature search of the subject revealed that different authors have done works on both marginal and non-marginal gas fields. Some of these works will be highlighted in this section and research gap identified.

Nematizadeh and Betpolice evaluated the Pars offshore gas field development plan comprising aquatic habitat, drilling, completion and surface facilities [8]. Siepel discussed the Arum gas field development plan and highlighted the concept of the mode of production design [9]. Also, they highlighted several solutions to problems faced by surface facilities. Ikoku elaborately highlighted the different technical requirements needed to be put in place for the development of gas field development plan [10]. El Feky presented a robust model for the development of a gas field which encompasses key parameters such as material balance for the reservoir, well deliverability for individual wells and gas sales contract [11]. Grant discussed a field development plan for a gas field located in Canada sited on federal lands which needed special considerations that are military related [12]. Seong *et al*. highlighted both the surface and sub-surface parts of a field development plan of gas field located in Malaysia [13].

Vilela *et al*. in their work developed a field development plan using Integrated Asset Management (IAM) methodology for gas field located in South West of Algeria named Reggane [14]. They used both geological and reservoir information to model the flow of fluids from reservoir to the end user, invariably generating a field development plan. Hong *et al*. discussed the steps followed to prepare a gas field development plan for a set of offshore gas fields located in Peninsular [15]. Their work also highlighted the method used for assessment of resource and subsurface

uncertainties management. Uwaga investigated the development of marginal fields in Niger Delta, Nigeria focusing on how economics and recovery can be improved [16]. Likewise, Safra and Antelo evaluated the process of project management for the development of a gas field focusing on technical review, quality control, organization structure and communication aspects of a project [17].

Ototoi *et al*. using a reservoir simulation model evaluated how to quantify the effect of static and dynamic uncertainties of reservoir using experimental design techniques, focusing on a gas field located offshore Niger Delta, Nigeria [18]. El Azm highlighted an overview of field development plan for seven gas fields in Egypt, focusing on the design concept to achieve zero flaring [19]. Sonde *et al*. highlighted the significant improvement recorded in the economic value of gas field named Zed field located in Niger Delta [20]. They stated in their work that this was achieved as a result of collaboration between various teams involved in the process. Nickie in his work discussed a field development plan that can be executed with existing in-country infrastructure for a gas field located in deep water, Trinidad and Tobago [21].

Akinwale examined how innovative technologies can be used for optimum marginal gas field development [22]. He itemized such innovative technologies as infrasonic passive differential spectroscopy, horizontal and directional drilling, acidizing, hydraulic fracturing, miscible gas flooding, thermal recovery and other enhanced oil recovery techniques. Akinwale and Akinbami worked on petroleum innovation system in Nigeria focusing on marginal oil and gas field operators [4]. The nature of interactions amongst players and stakeholders were examined. Also, they highlighted a framework which emphasized inherent advantages that can be accrued from interaction of elements in the petroleum innovation system which would enhance the production of marginal oil and gas field, was developed.

These reviewed literatures reveal that extensive work has been done on gas field development but there is still a research gap in literature for the development a template for marginal gas field development in Nigeria. Therefore this work becomes necessary and relevant to fill this gap.

Gas Field Development for Marginal Operators: A model field development strategy that would optimize the operations of marginal operators would be highlighted in this section. The key segments of gas field development which include commercial, technical, organizational, data analysis [23] and legal and regulatory framework [24] would be evaluated, focusing on how they can be improved for an optimized field development plan for marginal gas fields. However, it is important to state at this point that this study would not focus on any case study (specific marginal gas field) but would rather discuss on a general note an optimal template for field development plan for a marginal gas field. Hence, the following subsections would therefore discuss the key segments as follows;

Commercial segment of Marginal Gas Field Development: This segment of gas field development also referred to as Front-End Engineering Design (FEED) phase [14] is very important as it involves different teams shown in Fig. 1 working in collaboration to ensure that best economic decisions are made when designing and selecting ways to develop a marginal gas field. This is the most important phase of gas field development as it strongly determines the Total Project Cost (TPC). In this phase, it is imperative for marginal gas field operators to assemble the best team using the very best economic and technical tools that would ensure optimum decision is made at every given step.

In order to effectively carryout this phase successfully, it is imperative at the beginning to gather all input data such as reservoir and environmental data, choose and design systems components (examples are production drilling, wells, facilities and off-take systems) and make economic decision on that particular field development option. This should be followed by evaluation of the different field development options developed and intelligent identification of the most economic and technically feasible option best suited for the particular marginal gas field. At this stage of decision making, it is very important to consider the other field development options so as to ensure that the most economic and technical feasible option is taken amongst various options. Once a field development option is chosen, a conceptual design should be created for the particular gas field development option. The conceptual design stage is mainly focused on the designing off system components and elements.

For marginal gas field operators, it is pertinent that this phase be given utmost importance and attention as it determines the Total Project Cost which is a key parameter that affects the economic strength of the firm.

Table 2: Sample uncertainty resolution plan (reproduced from [23])

		WELL			
Sand	Uncertainty	Well Option A Q-02 Crestal Wall	Well Option B Q-07 Crestal Wall	Well Option C Q-02 down-structure Well	Well Option D Pilot Hole,with Q-02 Crestal completion
0-01 & 0-03	- Are both reservoir in communication	Yes	Yes	Yes	Yes
	- Is there an 0-01 oil leg	Yes	Yes	Yes	Yes
Q4	- Current Fluid Contact (GOC & OWC)	No	No	No	No
	- Is there by-passed oil available for development	No	No	Yes	Yes
Q5	- Current Fluid Contact (GOC & OWC)	No	No	Yes	Yes
	- Fluid Type	Yes	Yes	Yes	Yes
Q-14	- Reservoir communication between Q-14 & Q-15				
Q-15	- Fluid Contact (GWC)	No	Yes	Yes	Yes
	- Reservoir communication between Q-14 & Q-15				
	- Hydrocarbon presence on the right of the NW-SE fault	Yes	Yes	Yes	Yes
Q-17	- Fluid Contact (GWC)	No	Yes	No	No
	- Reservoir communication between Q17 & Q18	Yes	Yes	Yes	Yes
	- Fluid Type	Yes	Yes	Yes	Yes
	- Hydrocarbon presence on the right of the NW-SE fault	Yes	Yes	Yes	Yes
Q-18	- Reservoir communication between Q17 & Q18	No	Yes	No	No
	- Hydrocarbon pressure on the right of the NW-SE fault	Yes	Yes	Yes	Yes
Q-19	- Hydrocarbon pressure on the right of the NW-SE fault	Yes	Yes	Yes	Yes

Table 3: Data gaps and possible solutions [6]

S/N	DATA GAPS	ACTION TO BRIDGE THE GAP
1	Poor quality seismic data	Reprocess seismic and generate maps field
2	Well coordinate do not fall on maps	Carryout field survey to take coordinates of the well relative to other wells in the field
3	Some reviews do not have pressure data	Derive a field-wide transform base on levels with available pressure data and estimate the pressure for those reservoirs or perform static bottom hole pressure survey
4	No PVT available	Infer fluid type from well log and use correlations and analog data
5	No seismic data and reservoir surface available	Confirm well coordinates from the field and place on maps for further analysis, plan for seismic acquisition in the near future
6	No production data	Build static and dynamic models and carry out a more realistic production forecast
7	No SCAL data	Use correlation and/or analog data

Technical Segment of Marginal Gas Field Development: Marginal field operators are faced with various technical challenges such as improper well placement, well completion, fluid characterisation, drawdown, reservoir characterisation, unrealistic production forecast, poor reservoir development strategy, incompetent staffing and poor budget contracting [6]. Therefore, these challenges should be anticipated and ready solutions proffered and incorporated in the gas field development plan. Ambastha identified some of these technical issues faced and provided possible resolution options [23] as shown in Table 2.

Since a lot of the technical challenges faced in the technical segment of a marginal gas field development can be attributed to lack of reliable data at the field development planning process, it is imperative that a highly qualified and experienced team be assembled. This is necessary so that risks and uncertainties can be reduced and best decisions made with limited data. The work of Luo et al. highlighted techno-economic models for shale gas field development which can be re-evaluated and specifically tailored for marginal gas field development usage [25].

Data Analysis segment of Marginal Gas Field Development: Most at times in field development planning phase, data for effective decision making are not readily available. According to Ambastha the onus at this point lies on the team to go the extra mile to exhaust all available options to get all necessary data for an optimum field development [23]. Oyakhire and Omeke highlighted some possible solutions to data gaps experienced during marginal field development [6] as shown in Table 3.

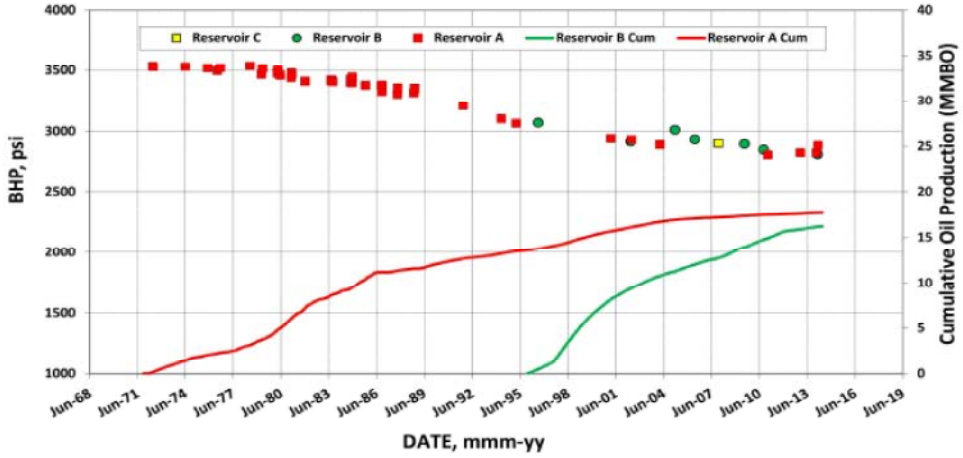

Fig. 4: Possible reservoir communication between three reservoirs (reproduced from [23])

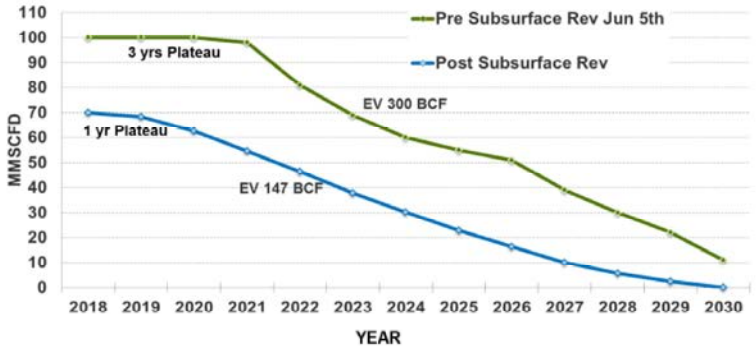

Fig. 5: Production profiles of a gas at different subsurface field data reviews (reproduced from [23])

After gathering all relevant data, the next step is analyzing the data so as to get useful information. It is very important to use the best analytical tools available for data analysis. Artificial intelligent tools such as machine learning can be very useful in this case because it will be get the job done in a more effective and efficient manner than traditional means of data analysis. A good data analysis can give insight into how different production and operation activities relate, ultimately ensuring that better decisions are made in developing an optimal field development plan. Fig. 4 shows how good data analysis revealed communication between three reservoirs (Reservoir A, B and C) whose static pressure and cumulative production data for nearly 40 years were collected and analysed [23]. A high point of this data analysis result is that it analyzed a reservoir which according to the author has not been produced yet.

Organizational segment of Marginal Gas Field Development: An important part of a gas field development plan is the organization and coordination of human resources available for the process. There must be a conducive atmosphere for all employees to critically evaluate all variables for the development of an optimum field development without boundaries [23]. It is imperative that there should be a functional communication link between employees with their peers, juniors and seniors alike to facilitate a proper feedback so that no valuable information would be excluded during critical decision making. Ambastha cited an example of how inadequate evaluation of subsurface field data resulted in the prediction of a production profile which is two times higher than when accurate review was carried out [23] as highlighted in Fig. 5. Hence, effort should be paid to human capacity development as it is paramount in building and developing a marginal gas field operators organizational strength. This can be achieved through mentoring, capacity building and regular peer reviews.

Legal and Regulatory segment of Marginal Gas Field Development: Also, legal and regulatory framework segment of a marginal field development is very pertinent. Since the Decree No. 22 of 1996 which gave birth to the Marginal Field Development programme,

there are still loose ends that need to be critically re-evaluated as regards laws guiding farm out of marginal fields to indigenous operators. These include ambiguity of terms in the decree, lack of compensation clauses for the marginal field owners and limitation of foreign equity holding to 40% which discourage investment by foreign partners etc. [24, 26]. However, Otombosoba and Dosunmu in their work reviewed guidelines such as Marginal Field Development Initiative, Petroleum Act 1996, Petroleum Amendment Act 1998, Petroleum Profit Tax Act, Nigeria oil and gas Local Content Act 2010, Guideline for the farm out and operation of marginal field 2001, proposed Petroleum Industry Bill and other policy documents guiding the oil and gas development in Nigeria, highlighted loopholes in these legislations and proffered adequate solutions [24].

Having reviewed the existing legislation guiding marginal field development, Otombosoba and Dosunmu made certain recommendations that could re-position marginal fields for improved production and overall national development [24]. These recommendations include existing laws should be amended so that foreign equity holders can be allowed to operate marginal fields, enact a wholesome and specific policy document for marginal field development that would guarantee incentives for local investors, payment of adequate compensation to marginal field owners and establishment of a single regulatory body for the management of marginal fields in Nigeria as against multiple regulatory agencies which creates regulatory conflicts. They also proposed that the Petroleum Industry Bill be passed and Federal Government should not benchmark marginal field operators using same standard as multinational oil companies.

CONCLUSION

This work has highlighted different segments of marginal gas field development. It opined challenges faced in developing an optimum field development template for a marginal gas field when drawbacks imperfect knowledge, risks and uncertainties exist. The work went further to proffer solutions and discussed a template that can be effective for marginal gas field development in Nigeria, drawing from the works of various authors that elaborately discussed the subject.

It is imperative to state that if the template discussed in the work is used a baseline for marginal gas field development in Nigeria, the anticipated increase in gas production from marginal gas fields and its antecedent multiplier effect on the economy may become evident soon.

Conclusively, it is recommended that optimization studies should be carried out on marginal gas field development plan using field data so as to develop an optimum field development template for marginal gas field operators.

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