GAS LIFT SYSTEMS DESIGN & OPTIMIZATION

A MODERN MODELING APPROACH

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About the Author

Manickavasakan S. Nadar (popularly known as *Manickam*) is a well-known expert, specializing in the field of petroleum production engineering and operations, artificial lift, system modeling, and optimization. With over 30 years of experience, he is a senior consultant and professional trainer in petroleum engineering.

Manickam has contributed to the improvement of efficiency in the design, operation, and troubleshooting of large-volume artificial lift operations, resulting in significant improvement of production and revenue. He had an illustrious career with Dubai Petroleum Company (then a business unit of Conoco Inc.), handling lead roles in production operations, well completions, artificial lift, asset modeling, and optimization. Later, he worked as a Principal Petroleum Engineer with Edinburgh Petroleum Services Ltd. (a Weatherford company), in Edinburgh, UK, and was responsible for development and implementation of optimization projects of many giant oilfields in the regions of Asia and the Middle East. He had also worked as a Senior Production Technologist with Margham Dubai, UAE. Before moving to the oil and gas sector, he gained a wealth of knowledge and experience in process operations at Asia's largest single-stream Ammonia plant, SPIC Ltd., in Tuticorin, India.

A strong believer in human creativity and use of technology, Manickam has helped clients move their offline production optimization to real time, sustaining huge benefits of optimization, including increased profits, reduced downtime, and energy savings. Manickam's contribution to gas lift engineering and operations using a lesser number of valves selected based on dynamic testing has improved the reliability of gas lift designs and led to cost reduction. His contribution to the improvement of network optimization software solutions, especially for well gas lift design and gas compressor modeling is noteworthy. His work has led the operation of many old fields with high water cut to become very economical.

During his career with Conoco and Weatherford, Manickam was actively engaged in mentoring his colleagues through in-house training sessions. As an independent consultant, he is now associated with development and delivery of training through PetroSkills®, serving the oil and gas industry across the globe. He has developed training content in his areas of expertise for many training courses. His focus is on achieving excellence through system optimization, a collaborative work environment, avoidance of redundant work, and the proactive contribution of individuals.

Manickam has a number of publications to his credit. He has made presentations in many Society of Petroleum Engineers (SPE) meetings and other international and regional conferences, on various topics related to artificial lift, well surveillance, and asset optimization. He served as guest trainer in artificial lift economics in SPE conferences in Cairo and Ahmedabad. He has won several awards from Conoco for his creative and innovative work and teamwork skills.

Manickam holds a BS degree in Chemistry from Madurai University, India and a degree in Chemical Engineering from Institution of Engineers (India). Apart from petroleum engineering, his passion includes Indian classical music and charity work.

Author's Note

HAVING WORKED WITH SEVERAL LARGE GAS LIFT SYSTEMS FOR THE PAST 30 YEARS, I am certain beyond doubt that there is always scope for improvement in gas lift operations. The quest for excellence in applying engineering investigations and setting up best practices with this versatile artificial lift system is ripe with rewards. This keeps engineers engrossed and constantly seeking opportunities for progress.

In the past three decades, as computers took up desk spaces, we found novel ways of refining gas lift technology by performing more field tests and analyses than ever before. This helped transform the *art* of gas lift to more of a *science*. Then came the communication explosion that facilitated sharing of these wonderful findings across the globe. As a result, the industry started applying engineering recommendations based on actual tests, investigations, and analysis, as opposed to the rules of thumb that had been previously followed. These developments allowed gas lift designs to become more accurate.

The spirit of growth did not stop there. The young and aspiring engineers from operating companies wanted to optimize their asset performance in a holistic manner, as opposed to merely solving individual well problems. This lit a new path in the industry. The service industry and operators collaborated in a big way and focused on the optimization of assets and networks, paying close attention to the performance characteristics of *every component of the network,* not just wells. Thus, the journey of network modeling and optimization took off. Time and again, case studies have proved the positive economic benefits of the gas lift system optimization approach. A more creative approach to system optimization not only opens up new possibilities, but also turns existing constraints and inefficiencies into profit-making opportunities.

What's more, moving to real-time surveillance and optimization yielded far more benefits than offline optimization, as this new methodology helped minimize downtime and production losses. The real-time optimization (RTO) application is able to readily identify the component or area of the field that is underperforming—making it possible to start appropriate remedial action right away. This is one of the key benefits of the "digital oilfield."

Always open to exciting innovation, the energy industry now uses the new data science—big data analytics, machine learning, and artificial intelligence—that is ushering in significant changes in the way the assets are monitored and optimized. Believe it or not, these powerful analytical tools possess human-like cognitive skills and are capable of modifying optimization algorithms by self-learning and training. As a result, more workflows get automated, downtimes are reduced, and efficiencies are further improved upon.

After successful implementation of the field operation center (FOC) for every asset, the industry has moved on to digital data integration for achieving inter-asset optimization through a real-time operations center (RTOC). The RTOC (Production) is extremely powerful in identifying synergies and maintaining high levels of efficiencies among many assets that are connected to each other with integrated production and export targets.

At every step of this innovative journey, the results kept improving the quality of oil and gas operations. Production was increased, and costs were reduced. Collaboration paid off as exciting solutions emerged.

Having had the privilege of being a part of this revolutionary industry in various roles, I have written this book as an attempt to capture how we optimize gas lifted fields using the modeling tools and communications technology available to us now. This book is intended for engineering and operations staff of operating and service companies, who work together to use technology intelligently to improve asset profits. All the information discussed is fully field-based and result-oriented. This book aims to provide you with the practical wisdom to embark on field gas lift system optimization using modern, pragmatic, applied, and proven methods.

Foreword
Paul M. Barry
Course Director, Production and Completions Engineering Division, PetroSkills LLC

SUCCESS IN OPTIMIZING A GAS LIFT SYSTEM to achieve both production and cost management goals flows from the sound application of informed technical reasoning and assumptions, supported by local knowledge based on technical, logistical, and commercial realities. That sound application originates in superior engineering design and then must be followed by the operations execution of a well-developed gas lift well completion and system optimization program.

Throughout his impressive career, **Manickam Nadar** has excelled in necessary strategic thinking and the resultant skilled application of both proven and emerging artificial lift principles and practices. Being an artificial lift expert, he is a leading industry consultant in gas lift and other artificial lift technologies. In the 15 years I have known Mr. Nadar, his work as oil and gas engineer, consultant, and subject matter expert for major oil companies, government national oil companies, independents, training organizations, and oilfield service companies has been fully professional, knowledgeable, precise, detailed, and complete. Underlying all these attributes is a full commitment to safe operations and the means and management vision to achieve such.

Gas Lift Systems Design & Optimization: A Modern Modeling Approach is a specialized professional book that covers all aspects of production optimization of gas lift systems. The book captures the depth and breadth of Mr. Nadar's comprehensive experience, bringing both leading-edge insight and practical methods to industry engineers and managers seeking the latest in optimizing gas lifted assets. Inherent in his approach in this text is the logic of a holistic design concept presented by Mr. Nadar that assures a comprehensive system methodology. The importance of blending a thorough understanding of fluid properties, fluid inflow capacities (oil, gas, water, condensate), gas lift design options, gas lift supply and production gathering facilities, operation of processing equipment, well and field management strategies, and several related parameters is demonstrated in this solid approach, which enables engineers to apply and achieve excellence in various key performance indicators.

My experience working side by side with Mr. Nadar in many oilfield production operations scenarios assures confidence in the precept that application of the practical principles and methods contained within the text will lead to proper choices made by engineers to maximize value from the application of gas lift technology in their producing assets. Newer, emerging technologies such as artificial intelligence, data mining, and digital twin, along with making use of the exponential improvement in modeling and optimization, combine to provide the reader with a Best-in-Class cookbook approach to designing and operating gas lift systems.

It is often proposed that gas lift is the most forgiving of all the family of artificial lift technologies. This principle is regularly observed as being accurate, and thus, gas lift well performance surveillance and precise decision making can provide a great understanding of what adjustments might be made to improve gas lift system performance. Methods explained in detail in the book provide a professionally written checklist of gas lift interrogation bullet points to adopt.

A point of emphasis often presented as a consultant is that oilfield operations management at various levels and disciplines must provide the means for the execution of well-developed ideas. Simply put, brilliant ideas disappear if "action," guided by commercial value assessment, does not follow a decision to consider a change when needed in the engineering, process, or equipment. This book provides the underlying basics for achieving quality and maximizing profitability in the performance of both individual gas lift completions as well as the overall field network. It also provides confidence that the practical implementation of principles of gas lift system optimization presented by Mr. Nadar will lead to positive results in any asset.

At some point, many oilfield engineers compile and assemble their career experiences to collect and organize their lifelong compendium of knowledge, know-how, and insights. Many do so just for the peace of mind achieved in "putting it all together." Others do so simply as part of their job responsibility to gather local knowledge in a particular company or geographical oil and gas basin. Regarding Mr. Nadar's approach to system modeling and optimization, the material contained in the book provides a solid, leading-edge, contemporary, technically accurate, and precise summary for engineers at any career stage—thereby enabling them to improve upon their understanding and application of artificial lift to maximize production and achieve commercial success for their oil and gas industry organization.

Paul M. Barry
September 28, 2021

Outline of the Book

This book presents efficient and practical ways of designing and managing gas lifted network systems from a field perspective. Maintaining peak efficiency in the operation of gas lifted assets is all the more important in today's environment. Gas lift system optimization methods described herein will establish that superior economic benefits can be achieved if each component of the production network is reviewed and optimized, instead of optimizing the well performance alone. The book will demonstrate how this can be achieved at a practical level. The book will also highlight the use of artificial intelligence, machine learning, and data science technologies that are available today to take asset optimization to greater heights and extend the benefits across various assets.

The book covers the following:

- How to improve performance of the production network by modeling every component of the network, along with the wells, and using the model-based optimization to run gas lift operations at peak efficiency, during normal operations as well as process upsets.
- How to make use of powerful real-time data visualization to identify underperforming components of gas lift networks and a real-time optimization system to maximize revenues and minimize operating and maintenance costs.
- How to utilize data transparency and transform asset operations to a collaborative working environment that enhances teamwork efficiency and helps an organization to achieve its key performance indicators (KPIs).
- How to optimize gas lifted wells, with special emphasis on unconventional reservoirs and deepwater gas lift operations.
- How to apply big data analytics, neural networks, and machine learning technologies to improve equipment reliability and plant availability. The goal is to spot areas of sub-optimal performance and correct them before incurring loss of production.
- How to integrate various assets inked to the hydrocarbon chain to identify synergies and promote inter-asset optimization. The real-time operations center (production)—RTOC (P)—can help integrate oil and gas operations within an organization or across multiple organizations in a country.

Chapters

1. Introduction to Gas Lift Network Optimization

This chapter introduces the use of well performance for gas lift optimization of a single well. Having discussed multi-well gas allocation and gas lift strategies, the concept of network optimization is introduced. The importance of the various components of the network such as pipelines, gas lift compressors, and separators is highlighted. This topic is an area that operators generally overlook, and, as a result, this omission causes serious system inefficiency, which is often expensive to correct.

2. Network Optimization Becoming a Reality

The foundation for establishing a versatile network system optimization is explained in this chapter. The factors to be considered during the evaluation and selection of the system optimization software are described in detail. The various steps involved in the implementation of system optimization have been explained systematically.

3. Modeling of Network Components

Details of the modeling of various components of gas lift production networks are presented. This includes fluid modeling and modeling of wells, pipelines, rotating equipment, and various other components of the surface network. Application of these concepts would help the reader fully understand the concepts of engineering modeling and gain the confidence to implement production optimization at the system level for any asset, of any size and complexity, irrespective of the software tools chosen.

4. Running the System Optimization Model

Finer details for running the model such as setting objectives and constraints for history match and optimization case studies are covered in detail. Many optimization scenarios of gas lift system optimization have been illustrated. This will help the user get the maximum value out of the system optimization model for solving day-to-day problems and evaluating the merits of project proposals.

5. System Modeling and Optimization Case Histories

Details of three real-life success stories are presented. These are case histories of design and implementation of gas lift system optimization in large assets. Also included are the practical challenges that were encountered during the implementation and the solutions provided in the projects. Factors that are critical for the successful implementation of gas lift system optimization are highlighted.

These should give the practical wisdom that is needed for the engineering and operation teams of the operator, as well as the service consultants.

6. Real-time Optimization

This chapter emphasizes the value of bringing data to desktop and implementing real-time optimization in assets. The need for and benefits of real-time surveillance and optimization of large production networks are presented. The intelligent systems that are used for implementation of real-time optimization (RTO) systems are described. How various KPIs are set, monitored, updated, and displayed in the real-time environment are captured. Sample displays showing various ways of visualization of results have been included.

7. Optimization of Unconventional and Subsea Gas Lift Wells

This chapter of the book describes the production optimization and artificial lift strategies of unconventional wells and deep water gas lift wells. New techniques of gas lift design & optimization of unconventional wells are covered in detail with supporting case histories. The challenges associated with deepwater single-point and riser base gas lift are highlighted. Gas lift optimization solutions have been presented for these cases.

8. Data Analytics and System Modeling

The eighth chapter takes the reader to the world of big data analytics and explores the impact of the digital transformation that is now happening in the oil and gas industry. The author explains how the advanced tools of machine learning, neural networks, and artificial intelligence can bring a sea change in the way the oil and gas industry will work in the future. The chapter explains how plant availability and uptime for critical machineries can be improved through predictive and prescriptive maintenance strategies using data analytics and machine learning models. How problems in gas lifted wells and networks can be identified is explained with sample data.

9. Digital Integration of Assets

The concluding chapter highlights the benefits of linking many producing assets and "customer units" through the concept of the RTOC (P). While field operations centers align the engineering and operations within each asset, the RTOC helps manage the inter-asset collaboration to ensure improved efficiency levels for all of the units. The digital integration of assets uses the physics-based and analytical models and identifies synergies across various operating units. The concept can be extended beyond a single organization to integrate upstream, midstream, and downstream operations of the hydrocarbon chain.

1

Introduction to Gas Lift Network Optimization

Production optimization of a gas lifted field always begins with wells. It is necessary to understand the heart of a well optimization—the gas lift response curve—generated for every well, using a well model. The "optimum" and "maximum" lift gas for a well and its current operating slope can be understood from the analysis of the gas lift response curve. Gas lift distribution to the wells in a field with a wide range of production capacities is always a challenge. The changes that happen to the wells and oilfield equipment over time represent another issue that would impact the gas distribution process. The ultimate solution for the optimization problem is to shift the paradigm from well gas lift optimization to "network production optimization."

This chapter discusses the following topics:

- Gas lift optimization using a well model
- The gas lift response curve of a well
- The concept of incremental slope
- Multi-well gas allocation
- Use of gas lift injection hit-lists
- Full network optimization

1.1 Well Gas Lift Optimization

1.1.1 Types of Production Optimization

In the oilfield context, optimization would mean either *increase production* (i.e., increase the flow rate from wells, maximize the reservoir production, or lower the mean failure rates) or *lower the costs* (i.e., reduce downtimes, maximize human resource potential, and do more with less).

There is a tendency to classify the areas of optimization based on where the tools are deployed or the parameters gathered from:

If more wells are added in the field over a period of time due to in-fill drilling, the production manifold pressure will gradually increase due to increased fluid load and congestion in the production gathering network. The production separator is usually operated at the same pressure.

In both these cases, the gas lifted wells are forced to flow against high wellhead flowing pressure. This will make the wells less efficient.

Pressure drop in gas lift side:

While the gas compressor performance may be normal, the gas lift header pressure at the platform may be lower than design, due to excessive pressure loss in the gas pipeline from compressor location to the wellhead platform. Length of the pipeline, restrictive ID, liquid loading, and gas flow rate exceeding the design may lead to this situation. This will result in shallow gas lift injection in wells.

The gas lift supply pressure may also be affected by compressor performance issues occasionally. This may have some impact on some wells but only for short durations.

In large fields, multiple compressors work in parallel to feed high-pressure gas into a common gas supply manifold. The gas lift rate to individual wells may be controlled by flow control valves working as gas lift chokes. If automated, these chokes maintain the set point gas lift rates to the wells. If set points are increased, more gas flow will be drawn from the compressors, and the compressors would work harder to maintain the discharge pressure with the increased throughput.

Fig. 1-13 shows the detailed schematic of a rotative gas lifted network. Also shown in the figure are some of the major parameters that can be varied to achieve the best operating conditions for the asset at any given time, subject to existing field constraints. The parameter that can be optimized is either pressure (P) or flow rate (Q) as marked in the network [(3)]. The items that add to the revenue are designated as +$ and the ones that add to costs shown as -$.

As a well is connected to both gas lift and production sides of the network, anything that happens to the network can affect the individual well performance. The reverse is also true—a change that happens in a well can affect the network too. For example, if a new gas lifted well is commissioned on a platform, depending on the sizes of the pipelines and flow rates, the gas lift manifold pressure may decrease and the production manifold pressure may increase. This can happen even if the gas compressor discharge pressure and the production separator pressure remain unchanged. This will affect the performance of other wells connected to the network. This is due to the fact that the injected lift gas is returned to the production system at low pressures along with produced fluids.

Along with the software, the company developed a three-step workflow process called *Aim-Gain-Sustain*™ and delivered successful network optimization solutions for many operators.

AIM:
The first step of the process is an Asset Inspection Methodology (AIM) that defines feasibility, business case, and costing.
GAIN:
The next step is engineering consulting work that gives a fast payback.
SUSTAIN:
The third step is to implement the technology, transform processes, and train people so that the operator can establish a sustainable production optimization system in the asset. This would be eventually maintained by the staff of the operating company.

This business model has a few key differences compared to the work done by traditional service companies. The process provides early value to the stakeholders, which pays for the implementation along the way. The biggest attraction of the process is that it integrates technology, processes, and people, as shown in **Fig. 2-1**. The workflows in the organization would be modified to accommodate the new optimization processes. People from the operating company would participate and get trained as a part of the project. This allows the operating company to take ownership of the optimization process and enjoy benefits for the long term.

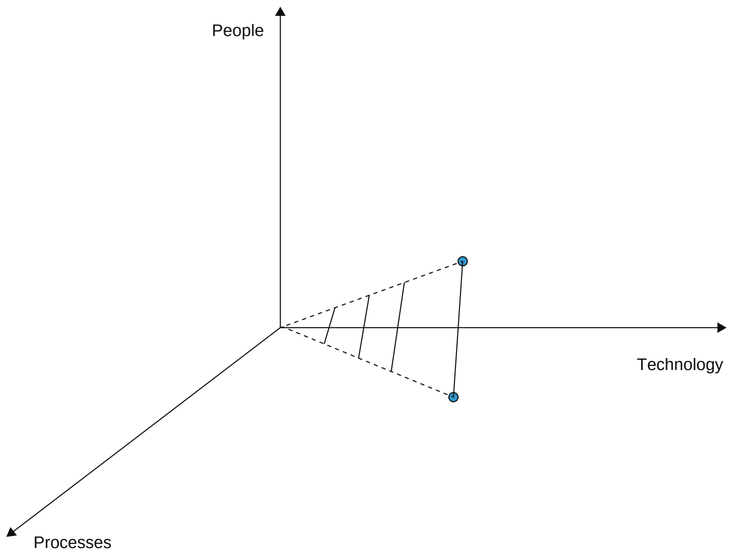

Fig. 2–1. Integration of people, technology, and processes

2.4.6 Scenario after Project Handover

It is common thinking that optimization is a one-time effort. This is not true. As the field changes continuously, the optimization too should be continuous. The frequency of optimization would depend on the business requirements and the size and complexity of the field. A large field with several hundred wells takes more time to stabilize after a change. Significant time will be required to collect a full set of field data if the data collection is done manually.

Some companies initially incline towards employing a Design and Evaluation Services for Clients (DESC) engineer from the consulting company as a part of their team; they use his or her special skills to take optimization forward. As observed in many assets, this approach may work for a short period (say, up to one year) but cannot continue forever.

The best option for the operator is to become self-reliant and take ownership of the optimization process. If there are some convergence issues with the model or if the model needs some upgrade or a major revision (e.g., addition of a new field to the model), the operator can utilize the service of a consultant engineer for a short period of time for the specific task. There would be a provision for this type of call-out service in the original contract. In many fields, over a period of time, the senior optimization engineers of the operating company become experts in the software and the model, because of their powerful hands-on experience with the model.

2.4.7 Routine Model Update

The biggest challenge for any field is to be able to continue the journey of system optimization over time. The model should be updated to represent the current conditions of the field before performing any optimization run.

As operations continue, the flowing characteristics of wells change with time. Some wells get shut in, and new wells come online. Produced volumes of fluids and ratios such as water cut and GLR change. Different pieces of equipment are pressed into service. Production lineup might change. Pipeline conditions will become different due to corrosion or solid / wax / scale build-up. Key operating parameters of the field might change. Keeping these in mind, the model should be updated and history-matched, if needed, before performing fresh optimization studies.

The most time-consuming aspect of updating a network model is re-calibration of well models. This involves a lot of work in assets with hundreds of wells.

The engineer uses the most recent well test data and performs nodal analysis to retune the well model. It may require adjustments to be made to the inflow or outflow parameters, or both, to get a good match for the measured production rate and flowing bottom-hole pressure.