Multi-Cycle Production Development Planning for Sustainable Power Systems to Maximize the Use of Renewable Energy Sources

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Abstract

This research focuses on the multi-cycle production development planning for sustainable power systems to maximize the usage of renewable energy sources. The intention of this study is to offer a comprehensive review of the research on the potential of multi-cycle production development planning for the development of sustainable power systems. In pursuit of this objective, the study has incorporated a qualitative research approach to analyze the volume of data available on the research topic to delineate how multi-cycle production development planning can be used for sustainable power systems and the maximization of the use of renewable energy sources. The study also highlights the major models that can be incorporated into the multi-cycle production development planning for sustainable power systems to maximize the use of renewable energy sources. The existing literature was extracted from databases, namely, Google Scholar, EBSCOHost, and Springer. The data comprised peer-reviewed journal articles, books, and credible online sources. Lastly, the practical and theoretical relevance of the study, along with limitations and recommendations for future practitioners, is provided in the conclusion.

Keywords: Multi-Cycle Production; Renewable Energy; Generation Evolution Planning; Sustainable Power; Energy Sources.

1. Introduction

Renewable energy's growing penetration is leading to big challenges for the power system's planning, development, and operations. Energy demand is growing incredibly. The industrialized nations account for 77 percent of the world's energy consumption and have 28 percent of the world's overall population. The current global population is projected to grow by 1.26 times by 2050, reaching 9.7 billion people. Most of the world's population, including 90 percent of the population increase, is found in emerging nations. The industrialized nations' energy usage won't rise by 2050, but they will adopt policies related to effective energy preservation [1]. The rising population all over the globe has strongly urged the need for multi-cycle development planning in renewable energy systems so that they can be implemented on

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a large scale. However, the limited research in this area proves to be a major barrier for organizations adopting multi-cycle development planning. To cover this gap, this research analyzes multi-cycle production development planning for sustainable power systems to maximize the use of renewable energy sources. Generation evolution planning (GEP) studies have been done in past decades. It plays a significant role in the development of the sustainable energy and power sector. To fulfill future load demand and maintain the security and reliability of the power system, it primarily seeks to obtain the maximum generation mix by examining the timing, location, size, and type of various candidate-producing facilities. It deals with the fluctuations occurring in renewable energy. The main objective of GEP is to reduce the high costs related to operations and investment [2]. However, boosting the use of renewable energy and lowering renewable energy curtailment have received increasing attention in power systems with huge renewable energy penetration.

Generally, there are two generation evolution planning (GEP) modules. In the first module, the generation mix is determined by the first module. The second module is used to inspect the generation mix's reliability and viability, previously determined by the first module. It relies on a probability-based and mechanistic method of production simulation. In past years, both these modules were used separately to minimize the computational load of generation evolution planning problems [3]. Despite that, the disadvantage of separated Generation evolution planning modules was that it could not provide an optimal expansion plan but a feasible one. Due to the recent rapid growth of computation capability, it is conceivable to merge both modules of investment decision and operational assessment in the Generation evolution planning model. This is also called the Generation evolution planning GEP model, which has specific operating limitations.

The benefit of integrating two modules is that GEP issues can more precisely represent power system operation at various load levels. Consequently, such GEP models could offer expansion plans with more reliable and cost-effective generation [4]. The detailed operating limitations in GEP problems have been modelled using many different strategies up to this point. The most popular method is to build many load blocks by using the load duration curve (LDC), where each block represents a single load level and the associated duration. The GEP models would then include the operational restrictions for all load levels. Numerous GEP issues, including natural gas systems, multi-area GEP, combined power expansion co-planning, single-area GEP, and investment within the electricity industry, have been addressed using this strategy. The advantage of this strategy employing load blocks is that it requires less processing than takes into account all operating constraints over many days. Nevertheless, as load blocks are from a single period, they are unable to capture the ongoing volatility and unpredictability of renewable energy sources (RES). The primary goal of the GEP model is to reduce overall costs, such as operational and investment costs. In reality, these cost-effective GEP models can significantly limit RES in electricity networks with substantial RES penetration. However, recently, more focus has been placed on boosting renewable energy usage and lowering renewable energy constraints [3]. To increase the capacity for renewable energy generation and make power systems as "green" as feasible, it is imperative to create a revolutionary GEP model.

Renewable energy comes via natural processes that are constantly replenished. Many renewable energy sources acquire their heat either directly from the sun or the earth's crust. This concept also includes hydrogen produced from renewable sources and energy and heat produced using sun, wind, ocean, hydropower, biofuels, etc. Solar power, wind power, hydroelectricity, micro-hydro, biomass, and biofuels are examples of renewable energy technologies. The growing industrialization and human labor are increasing environmental pollution [1]. The usage of renewable energy, its security, pricing, policies, and renewable energy implementation are the primary topics of sustainable development.

The main aim of this research paper is to analyze multi-cycle production development planning for sustainable power systems to maximize the use of renewable energy sources. On the basis of this aim following objectives are drafted.

- To find out how sustainable power systems help maximize the use of renewable energy sources.
- To find the use of generation evolution planning in terms of lowering operational and investment costs.
- To assess the sustainability status of generation evolution plan.

This research has a great significance for developing sustainable power systems to maximize the use of renewable energy sources. Sustainable power systems provide huge benefits not only to the environment but also to the economy globally. Since not all people in developing countries have access to electricity, achieving sustainable power generation is difficult and essential for sustainable development. But, especially for developing countries, preparing a long-term, sustainable, futuristic power generation system is vital. The world's energy requirements are currently exceeding the available generation capacity on a global scale. Therefore, it is important to effectively and securely address energy requirements. Renewable energy sources should be used to enhance the energy solutions. The addition of renewable energy to global primary energy is still insufficient to meet fundamental electricity and power needs. This topic is crucial to environmental issues, which lead to high pollution, and it becomes important to find sustainable solutions that can reduce pollution and the total costs and improve the economy. As a result, this research provides a great insight into the industry in developing sustainable power systems that can maximize renewable energy sources' consumption.

The scope of the research is limited to Russia, where the target population is a power industry familiar with using sustainable power systems to increase the use of renewable energy sources. The research covered 100 people from energy firms as respondents. Many factors are related to the current research, but this study has followed only a few factors to support the research and description, which are multi-cycle production development planning, sustainable power systems, renewable energy sources, and generation evolution planning.

2. Literature Review

2.1. Importance of a Sustainable Power System

The word sustainable in energy or power generation can be referred to as the production of energy that can be used infinitely in abundance, not only by the current generation but also by the upcoming generations. Sustainable power systems have become a crucial need of time as the generation of energy using fossil fuels not only accounts for the harmful effects on the environment causing global warming but is also an unreliable means due to its finite resources [5]. To generate these sustainable energies, there is a certain cost attached; however, the energy itself does not cost anything. This sustainable energy includes solar energy, wind energy, and water energies, also known as hydropower and geothermal energies. A sustainable energy source has various benefits. Firstly, it does not have any negative impacts on the health of the people, while generating energy by burning fossil fuels creates not only air and water pollution but also has a significant on people's health, causing neurological issues for them, breathing problem, cancer, or heart, early deaths. Moreover, the generation of sustainable energy proves to have zero carbon emissions, which can help save the environment from hazardous effects in the form of global warming [6]. Hence, the need of the future demands an energy source that is secure, reliable, and at the most affordable prices available to all consumers as the population is increasing rapidly, as never before, the need for sustainable energy has become vital as fossil fuels are depleting more rapidly, causing them to more expensive than ever. Currently, many sectors, including small and medium scaled industries and companies, can see incorporate these sustainable power systems on a small basis. People are even deploying these energy resources, especially solar energy in the form of solar panels, into their homes, getting influenced by the concepts of smart homes through the integration of smart meters, etc. This is why it can be predicted that very soon, more people will opt for such options.

2.2. Multi-Cycle Production Development Planning

The concern about energy generation through fossil fields and its impacts social and environmental impacts can only be mitigated through the integration of sustainable energy resource models. The term multi-cycle production development planning refers to the concept that includes the different phases or stages a certain product goes through before coming into the final consumption product. This product life cycle comprises five to six stages: production, transmission, distribution, conversion, storage, and, lastly, consumption [7]. The development of sustainable energy development includes various objectives that help in the management of different environmental, economic, or social factors. Currently, the sustainable development of energy has become the most important topic for many governments to develop by removing the environmental effects economically. However, there are some major aspects that the countries should focus on, while the generation of sustainable energy, according to the MESEDES model, revolves around the multi-area, multi-stage, and multi-objective aspects [8].

The main objective of this model was to first minimize the cost as possible in the investment or the operational cost in the development of sustainable energy projects. The second objective is to reduce greenhouse gas emissions while generating energy from power-generating plants. Lastly, the objective of the model was to increase the supply of the sources of energy imported. Another model for comparing and analysing effective alternatives for decision-making in product development is the PROMETHEE model [9]. This helps provide the overall results of the efficiencies of all energy alternatives in the form of color mapping according to the preferences of the energy alternatives. This model does not undermine any alternative or means; instead, it prioritizes them in a decision-making process for sustainable energy planning.

2.3. Role of Multi-Cycle Production Development Planning for Sustainable Power Systems in Maximizing the Use of Renewable Energy Sources

In the decades, the demand and use of electricity have increased more than ever, depleting non-renewable resources. Currently, demand has increased for generating energy through resources not harmful to the environment or human beings. This has led the energy sector to plan these developments in more detail revolving around multiple factors like environmental, social, and economic aspects. Governments in different countries are emphasized implement such policies that encourage the integration of sustainable renewable energy resources to maintain environment-friendly economic development [4]. For example, the policy of the feed-in tariff has been widely implicated and has been successful in many countries that are providing the producers of such energy (whether through wind or solar) an above-the-market price for what they produce or deliver to the grid by the government.

The main challenge in the development of a sustainable power system in maximizing the use of renewable energy sources is to increase the availability of affordable, appropriate, and dependable energy supplies. However, to make effective and efficient decisions during the production process, the use of different methods like Multi-criteria decision support methods (MCDM) is essential. This method mainly provides a solution to the five basic problems in the decision-making process faced in the development of renewable energy [10]. These problems mainly include the selection of the means or the source of the energy supply. The MCDM method allows the consideration of various opinions of the stakeholders in the form of metrics aiding in the decision-making process. The location also derives an important decision to consider, which is better made while using the MCDM techniques as it helps in finding the ideal location by selection based on specific standards set. In sustainability factors, these methods help in identifying the best sustainable alternatives while eliminating the minimal performing alternatives by prioritizing in ranking. The evaluation of these problems can be done based on alternatives or the classifications of certain standards. The other model that is used for assessing the variation in renewable energy sources is the Generation Expansion Planning Modal (GEP). The increased concept of renewable energy brings significant challenges in the planning and operational setup of these projects; hence, encountering those hurdles, this approach is used. The GEP model revolves around the concept of only total cost minimization [3]. Furthermore, to meet the future needs or demands of the people and mention the dependence and security of the power generation, the GEP model essentially seeks to obtain an optimal generation capacity by evaluating different variables like time, location, and alternatives. This is why the generation Expansion Planning Model (GEP) provides a detailed and better planning approach for using sustainable energy.

In the energy sector, to maintain and generate power from these clean sources like wind, solar, water, hydropower, and geothermal energy need to integrate these methods or models for effective planning for a sustainable power system. These methods help in figuring out the multiple problems or the conflicting areas while providing the best alternative or solutions ahead. However, the renewable, sustainable power system suffers some significant hurdles. Some of the prominent ones among them are the absence of the integration of the policies or regulations by the government, which is preventing people from benefiting from those sustainable technologies. Also, the lack of awareness programs by the government is causing a certain hindrance in people integrating these technologies. New policies to attract investors and the public need to be made [11]. Besides, the governments of different countries should also emphasize releasing funds for R&D of this renewable energy sector to have a sustainable energy future. Lastly, the inadequate and costly supply of renewable energy sources also occurs as a factor in losing customers. Renewable energy sources do diminish one's energy cost with a reduction in taxes, but it initially needs a handsome investment that might not be affordable for many consumers. This is why governments in different countries should focus on the development of these energy resources or equipment locally rather than importing, which will eventually result in lower prices that appear affordable for many consumers.

3. Research Methods

The flowchart of the research methodology that was used to achieve the study's aims is shown in Figure 1.

Figure 1. Flowchart of the methodology

3.1. Philosophy

For this study to explore the significance of multi-cycle production development planning in maximizing the use of renewable energy sources for a sustainable power system, interpretive philosophy of research is deemed appropriate. The selection of the research philosophy is based on the qualitative and secondary nature of the study, since interpretive research tends to maintain a subjective approach to exploring the research phenomenon. The reason why the philosophy is considered suitable is that it will allow the researchers to conduct an in-depth analysis of the why, what, when and how related questions regarding the significance of multi-cycle production and how the approach can help determine the sustainability of power systems [12]. Moreover, the interpretivism philosophy will also allow the researchers to determine the role of multi-cycle production development in maximizing the use of renewable energy sources. Thus, the interpretive paradigm facilitated the meaning-making process and helped in generating observable outcomes for the topic under discussion [13].

3.2. Design

To support the interpretivism research philosophy, a qualitative research design is opted for by the researcher to explore the topic under scrutiny. Qualitative research entails collecting and analyzing non-numeric data to gain an in-

depth understanding of the research phenomenon under study. Moreover, the qualitative research will also facilitate answering all the key questions subjectively to investigate the role of multi-cycle production development planning for sustainable power systems to maximize the usage of renewable energy sources. The reason why a qualitative research design is deemed appropriate for this study is that it allows for providing insights into a specific phenomenon within the industry [14]. And since the qualitative research design does not require the recruitment of a sample and the usage of extensive methods, the approach is also considered inexpensive with regards to quantitative approaches. The rationale of focusing on the details and providing extensive discussions on the research topic makes the qualitative research design an optimal choice in determining the role and feasibility of multi-cycle production development planning. Moreover, since qualitative research design is capable of monitoring and reporting changes in a given research phenomenon [15], the design is considered relevant in exploring the usage of multi-cycle production development planning in maximizing the use of renewable energy sources.

3.3. Approach

According to Danermark [16], case studies are an effective way to generalize the findings of a specific research process that helps contribute positively to enhancing the knowledge regarding the research phenomenon. The case study approach to research can be applied to both qualitative and quantitative research designs. For this study, the case study approach is used as a qualitative source to add to the knowledge of the researcher predominantly on the research topic regarding the role of multi-cycle production development planning in maximizing the use of renewable energy sources for sustainability in power systems. The reason why the case study approach to research is deemed appropriate is that it allows the researchers to explore complex phenomena by identifying the key yet distinctive factors that can influence the research outcomes [17]. For instance, this study uses a qualitative case study to investigate the factors that have the autonomy to influence the role of multi-cycle production development planning in maximizing the usage of renewable energy sources. The understanding of these factors will subsequently influence the sustainability capacity of power systems, which is the focus of the study at hand. The key reason behind the selection of qualitative case studies for this research lies in the ability of the approach to provide rich information on the research topic, which in turn provides insights for further exploration of the research topic [18]. Hence, the researcher opted for a qualitative case study approach to explore the research phenomenon mentioned in the topic to yield detailed insights into the role of multi-cycle production development planning.

3.4. Data Sources and Collection

Secondary data collection in research refers to the usage of already existing information to conduct the research at hand. Secondary data use the works of other authors in the respective research fields to conclude on the research at hand. The usage of pre-existing data to explain a research phenomenon allows the researcher to perform thematic analysis available through various credible sources [19].

For this study, the researchers aimed to keep a secondary approach as the research develops a relationship between multi-cycle production development planning and sustainable power systems on the maximization of the usage of renewable energy sources. The reason why secondary data are collected for the study is that it will allow the researcher to analyze the volume of data available on the research topic to establish relationships among the variables under study. Moreover, since the data is already available in large volume, this will allow the researchers to analyze the trends and changes in the role of multi-cycle production development planning over time without having to wait for extended durations to collect relevant information. Similarly, the collection of information from secondary sources facilitates the analysis of ample information, which improves the generalizability of research outcomes. Secondary sources also helped the researchers understand the competitive landscape for multi-cycle production development planning while also supporting the use of the same in maximizing the use of renewable energy sources by understanding and exploring the prevalent trends in the industry [20]. This facilitated the discussion of sustainability in using multi-cycle planning to improve the use of renewable energy sources. Also, secondary sources of data collection will allow the researcher to maintain control over the data collection process, which will help in the conduct of a cleaner and structured study. Hence, based on these benefits and the economical nature of the data collection method [21], a secondary data collection approach is deemed appropriate to investigate the research phenomenon at hand. Different databases like Google Scholar and IEEE Access were searched to retrieve relevant literature. Different keywords like "multi-cycle planning development for renewable energy systems" were used to find the most relevant articles for data collection. Also, it was ensured that the most recent information was accessed so that the findings of the study were accurate.

3.5. Research Instrument

To collect secondary qualitative data, the researchers will use following databases as the research instruments to explore the role of multi-cycle production development planning. These sources include Google Scholar, EBSCO Host, and Springer. Peer-reviewed journals, articles, books, and other credible online sources will be used to collect information and analyze the trends regarding the research topic.

3.6. Data Analysis

To analyze the data collected through the abovementioned research instruments, a thematic analysis approach will be suitable. The reason why the approach is selected is that it facilitates the analysis of qualitative data to interpret the meaning, themes, concepts, and relationships among the variables under investigation. This is done by determining the presence of certain keywords and themes that are already present in the pre-existing qualitative text. Once the data are categorized, drawing conclusions based on the trends and consistency can be made regarding the phenomenon under study [22]. The researcher conducted the thematic analysis for this research by classifying the collected data into different themes, like technical advantages of multi-cycle production planning for sustainable energy systems, the need for renewable energy resources, and models for renewable energy systems. The papers and articles reviewed during the study were classified into these themes, and their main findings were examined to produce deeper insights into the future of multi-cycle production planning for sustainable energy systems.

3.7. Ethics

The ethical considerations for this qualitative secondary research include the reasonable presumption of consent from the study subjects along with the de-identification of the data before its release to the researcher. Other considerations include the avoidance of over-exaggeration of information used in the study process, along with proper acknowledgments and citations of the works used in the research [12]. The work of each author used as a source of information must be properly referenced to avoid misuse. Also, miscommunication must be avoided at all costs to ensure the credibility of the research and its outcomes [23]. Thus, transparency must be maintained at all costs as a duty toward the public and scholarly community, along with ensuring that the information presented is trustworthy and complies with the rules of conducting research for extreme credibility.

4. Results and Discussion

4.1. Introduction

This section discusses the findings of the study based on the results and investigations of previous credible studies. Thematic analysis has been conducted to determine the major and repeated themes and ideas across the datasets. The parameters pertinent to the development of Multi-Cycle Production and Sustainable Power Systems have been selected on the basis of the review of the extant literature. The discussion highlights the importance (and role) of the Multi-Cycle Production development and planning for the Sustainable Power System and Maximized Use of Renewable Energy Sources. The discussion also highlights the major models that can be incorporated for efficient multi-cycle production scheduling and optimal power generation configuration. These specific parameters for the literature analysis and findings have been chosen to shed light on how Multi-Cycle Production development and planning can pave the way for the Sustainable Power System and maximize the use of Renewable Energy Sources, as well as to propose specific models as a starting point for the adopters of multi-cycle production scheduling.

4.2. The Need for Renewable Energy Sources and the Importance of Sustainable Power Systems

From the analysis of the extant literature, it is found that the incorporation of renewable energy sources for developing a sustainable power system has evidently become a need, given the depleting energy sources and the rising global demand for energy consumption. From the preliminary research, it was found that industrialized countries are characterized by 77 percent consumption of global energy reserves. In this regard, industrialized countries are seeking to increasingly adopt policies and mechanisms aimed at effective energy preservation to accommodate their rising demand for energy consumption [1]. Furthermore, the need for sustainable energy systems has been exacerbated by the recognition of the harmful effects of the generation of energy from fossil fuels in terms of environmental degradation, resource depletion, and health issues due to air and water pollution. In this regard, the sustainable energy that is produced from renewable sources does not have such negative effects on the environment or on the health of individuals. The generation of sustainable energy enables industrialists to eliminate and reduce their emissions of greenhouse gases and carbon, which ultimately contribute to the sustainability of the environment and the prevention of global warming [5, 6].

One of the most important advantages of a sustainable energy system using renewable energy sources is its abundant supply. The renewable energy sources are infinite, contrary to the fine energy sources of the world. These energy sources are safe and hygienic energy sources with a significantly less negative impact on the environment than traditional fossil fuel-based energy systems. The use of the sustainable energy system also contributes to significant cost reductions as the investment in renewable energy is mostly associated with the materials and labor for the construction and maintenance of facilities instead of the expensive energy imports. Renewable energies are reliable and abundant and can be very cheap if sustainable power systems and supporting infrastructures are developed. These sources include wind, water, solar, geothermal, biomass, and tidal power. However, non-renewable energies, such as coal, natural gas, and oil require high-cost exploration as well as high-risk drilling and mining operations. In this regard, there exists a high need

for developing energy systems that are safe, reliable, as well as affordable. As the global population grows at an unprecedented rate and fossil fuels are being depleted faster and more expensively than ever before, the need for sustainable energy is becoming essential. Many sectors around the world, including small businesses, are now observing the small-scale integration of these sustainable energy systems.

4.3. Technical Advantages of Multi-Cycle Production Development Planning for Sustainable Power Systems and Maximized Use of Renewable Energy Sources

In addition to general sustainable production, the production of energy in the context of industrial production has remained a great concern. The analysis of the extant literature has highlighted that researchers have identified two ways that can be incorporated into industrial production to increase energy efficiency and make energy systems more sustainable. A way is to invest in new energy-efficient production machines and design new production processes. Another method is to develop energy-oriented production development planning systems. Previous approaches pertinent to technology investment are usually associated with high costs, but production planning is of particular interest to practice and research as it enables improved energy production and use at low investment costs [24–27].

As the name suggests, multi-cycle production development planning involves various phases or stages that are involved in the production of a product through which a given product passes before entering the final consumption stage [7]. In this context, the development of a sustainable power system entails the development of the appropriate cycles of production while ensuring optimal management of various environmental, economic, or social factors. A major consideration of this model is to facilitate the minimization of the operational cost in the production of energy, ensuring a more sustainable energy production system and facilitating a reduction in the emission of greenhouse gasses during the generation of energy. Lastly, the model also facilitates the efficient supply of energy with the use of renewable energy sources [8].

Power generation expansion and production development planning play a central role in the context of the development of sustainable power systems [28, 29]. The purpose of the power generation expansion or production development planning is to determine the optimal power generation configuration by determining the time, production size and capacities, location, and type of the various power generation facility in question, primarily to meet potential energy demands and ensure the reliability and safety of the power system. Production development planning involves determining the optimal generation mix that can facilitate meeting the energy consumption demand and electricity demand loads [30]. In the context of energy generation, the planning period ranges from a few years to decades. Thus, production development planning must be divided into appropriate planning models involving enough production cycles [31, 32]. Thus, effective and appropriate product development planning involving adequate production cycles appears to be an effective way to develop sustainable power systems in the countries and contribute to the efficient use of renewable energy sources. The study by [33] performed research on multi-cycle planning and development in China. It was noted that multi-cycle planning and development in renewable energy systems significantly enhance efficiency as it leading to improved maintenance performance and reduced chances of outages. Therefore, the system is in operation at all times to serve the needs. Additionally, another study conducted in China found that the use of multi-cycle development planning in renewable energy systems is very effective in enhancing the implementation of the systems as it reduces the lead time for sourcing materials and deployment of the plan. Also, it helps in making renewable systems more efficient and safer to operate over long hours [34, 35].

4.4. Multi-Cycle Production Development Planning Models for Sustainable Power Systems

Various models have been proposed in the extant literature aimed at efficient multi-cycle production scheduling and optimal power generation configuration in terms of time, production size and capacities, location, and the type of the various power sources. In the context of industrial production development planning, one of the major planning models aiming at adequate production cycle planning is a hierarchical production planning, as proposed by Claus et al. [36]. The hierarchical production planning model entails decisions pertinent to the appropriate planning levels, such as intensive production planning, lot sizing, and master production, as well as the decisions for the production time schedules. In short, hierarchical production planning facilitates the scheduling of the production cycles in terms of time horizons involving a few years to decades [36].

In the context of hierarchical production planning, one of the major planning development models for production cycles is the master production schedule. This energy production planning covers all product segments of the energy on the production floor coupled with its key constituents and the requirements related to production capacity. The purpose of the production model is to develop production cycles over several time and coordinate these cycles between different production sections. Thus, the model facilitates the development of an appropriate cycle for the production of energy. The starting point for production planning is a short-term forecast of existing demand and load orders of the energy and final product demand. The resources required can be organized into groups and units that have the same functionality and the same cost burden. This facilitates the minimization of the cost of associated production, storage, and resources

based on a specified production cycle [37]. Another model aimed at the development of effective and efficient production is multi-criteria decision support methods, which primarily provides solutions to the various basic decision-making problems facing renewable energy development, including the choice of power source, opinions of various stakeholders to be considered in the form of key figures to support decision making, location and time scheduling of the energy production [10]. With respect to sustainable power systems, this model facilitates the optimal mix of renewable energy sources and the development of the appropriate production cycles for addressing the energy consumption demand with renewable energy sources.

Another model discussed in the extant literature for the configuration of renewable energy sources and the development of energy generation cycles is the Generation Expansion Planning model. The increase in the concept of renewable energy presents considerable challenges to the planning and operational structure of these projects. Therefore, this approach is used to overcome these hurdles. The Generation Expansion Planning model facilitates the efficient production of energy and the minimization of costs [3]. To meet the potential demand for energy and to ensure the dependence and safety of power generation, the GEP model evaluates various variables, such as time, place, alternatives, production capacity, etc. for optimal power generation. For this reason, this planning model provides a more detailed and superior planning approach for the use of sustainable energy. The energy sector uses these methods or modalities to effectively plan sustainable energy systems to conserve and generate electricity from clean energy sources such as wind, solar, hydro, hydro, and geothermal need to be integrated. This production planning model facilitates the identification of multiple problems or conflicting areas as well as the most appropriate alternatives or solutions in advance [11].

A major model that has been widely incorporated for the maximization of the use of renewable energy sources in production planning is the multi-energy complementary system. The multi-energy supplement system for the production planning of the energy uses large integrated power plants that combine the benefits of wind, solar energy, hydraulics, coal, natural gas, and other resources, and a large energy storage facility. With the incorporation of this production planning model, not only can take advantage of the rapid adaptability of hydropower, but it can also supplement the active power of your solar power plant. Not only can you take advantage of the rapid adaptability of hydropower, but they can also supplement the active power of your solar power plant. Combining photovoltaic and hydropower to improve the quality of photovoltaic provides the system with relatively stable and reliable production and supply of energy, promoting the maximized use of renewable energy and abandoned wind and solar energy [38, 39].

Complementary multi-energy systems typically include thermal power (such as gas turbines), wind power, photovoltaic, hydropower, pumped storage, and other sources of energy production [40, 41]. In this traditional scheduled production planning for energy sources, the levels of the thermal power to be used can be adjusted to a specific peak amplitude, resulting in slower output speeds. Similarly, the gas turbine unit can be quickly started and stopped and would be used as s a backup and peak power source for the production of the energy and primarily withstands the peak demand for the energy. Hydropower plants with balanced power can realize greater capacity benefits with water storage control, wind power, and photoelectric compensation operations. Pumped storage power plants can take over the fast response capabilities and tasks of grid systems and enhance the grid's ability to absorb wind energy and photo electricity [39, 42]. Lastly, another model that can be discussed in this context is the PROMETHEE model, which is used for the analysis and identification of effective alternatives [9]. This model can assist in the identification and analysis of the efficiencies of all energy alternatives that can be incorporated for the production of energy.

All in all, various models of product development planning have been proposed that can be incorporated for appropriate planning of the production cycles that would aid in the development of sustainable power systems and maximization of the use of various renewable energy sources. Additionally, governments of various countries must emphasize the release of funds for R&D in this renewable energy sector to realize a sustainable energy future. It is imperative for the government to identify an appropriate model for developing a sustainable power system for the industrial section and make investments accordingly. Table 1 summarizes and juxtaposed the features of the aforementioned models.

Table 1. Multi-Cycle Production Development Planning Models for Sustainable Power Systems

Hierarchical Production Planning	Multi-Criteria Decision Support Methods	Generation Expansion Planning Model	Multi-Energy Complementary System
Based on time horizons and short-term forecast; Planning entails lot sizing and master production (all product segments of the energy) with time schedules; Develop production cycles several times and coordinated with production sections; Reduces cost of production, storage, and resources.	Based on the opinions of various stakeholders; Decides location and time scheduling of the energy production; Decides the optimal mix of renewable energy sources and appropriate production cycles.	Based on the evaluation of variables, such as time, place, alternatives, production capacity; This leads to the efficient production of energy; Reduces costs.	Leverage the combination of wind, solar energy, hydraulics, coal, natural gas, and other resources; The combination provided stable and reliable production and supply of energy.

4.5. Summary

This section discusses the findings of the previous studies pertinent to the multi-cycle production development planning for sustainable power systems to maximize the use of renewable energy sources. The findings are drawn from three themes; the need for renewable energy sources and the importance of sustainable power systems, technical advantages of multi-cycle production development planning for sustainable power systems, and maximized use of renewable energy sources and multi-cycle production development planning models for sustainable power systems. In summary, the section on the production cycles of energy generation can pave the way for developing a sustainable power system as well as the efficient and maximized use of renewable energy sources. The section also highlights various models that can be incorporated for developing a sustainable power system with adequate production scheduling planning that facilitates the efficient planning of production cycles and the appropriate configuration of renewable energy generation.

5. Conclusion

5.1. Key Findings

This study investigated the potential of multi-cycle production development planning for developing sustainable power systems aimed at minimization the use of renewable energy sources. The rationale for the study is embedded in the fact that the global demand for energy consumption has been rising while energy sources are being depleted. Simultaneously, the conventional generation of energy from fossil fuels leads to the degradation of the environment and various chronic and severe health conditions. In this regard, there exists a need for the incorporation of systems that involve sustainable energy that is produced from renewable sources and, thus, do not have much impact on the environment or the health of individuals. This need has been highlighted and emphasized in the extant literature. It is asserted that the need for sustainable power systems has been rising owing to the rising recognition of the harmful effects of fossil fuels on the environment and the rising global warming. Concurrently, the rising awareness regarding the positive impacts of sustainable energy in terms of zero carbon emissions has contributed to an increased need for sustainable energy systems [5, 6]. The article analyzed the importance of sustainable energy and suggested that the generation of sustainable energy has become crucially important to enable industries to eliminate and reduce their emissions of greenhouse gases and carbon that contribute to environmental sustainability.

In this recognition, the paper has highlighted that a major concern in the development of a sustainable energy system has been the production of energy that would assist in addressing the global energy demand as well as maximizing the use of renewable energy sources. Thus, production planning is of particular interest to practice and research as it facilitates improved energy production and efficiency. The analysis of extant literature highlighted that traditionally, technology investment in the industrial context was more focused on cost reduction; however, at present, greater emphasis is on production planning to improve energy production efficiency, which ultimately reduces cost as well [24–27]. In this context, it is found that effective and appropriate product development planning entails decision-making about the adequate production cycles for generating the energy that can enable the countries to ensure efficient use of renewable energy sources and the incorporation of sustainable power systems. It is asserted by a previous study that effective product development planning facilitates the way for sustainable power generation, minimizes the operational cost, and reduces the emission of greenhouse gases, which truly makes the energy production system sustainable and efficient [8].

In this regard, this paper highlights the potential of multi-cycle production development planning to contribute to the development of sustainable power systems. Conclusively, the use of renewable energy sources can be maximized by determining the optimal power generation configuration and the appropriate time, production size and capacities, location, and type of the various power generation facilities. The paper has discussed various models from the extant literature for production development planning that can be adopted for the appropriate scheduling of the production cycles as well as the optimal power generation configuration, including the hierarchical production planning model, master production scheduling model, multi-criteria decision support method, Generation Expansion Planning model, multi-energy complementary system, and PROMETHEE model.

The present article makes theoretical contributions to the relevant extant literature regarding the role of multi-cycle production development planning for sustainable power systems. The article has rebounded to the relevant literature by highlighting the role of multi-cycle production planning in paving the way for developing multi-cycle production planning. Along with the theoretical contributions, the article also offers practical insights to industrialists, energy producers, and their associated managers and practitioners in terms of the potential of multi-cycle production development and planning and the specific models that can be incorporated for effective and efficient multi-cycle production scheduling and optimal power generation configuration.

5.2. Strength and Limitations

Given the rising importance and the need for developing sustainable power systems and the incorporation of renewable energy sources, this paper has offered valuable insights that can aid in the development of sustainable power systems with appropriate scheduling of production cycles and optimal power generation configuration. The strength of

this study is embedded in its use of credible previous research and combining their findings to provide a comprehensive review of the appropriate product development planning model for the scheduling of production cycles and adequate use of renewable energy sources. Nonetheless, despite such valuable insights and contributions, the study also accounts for certain limitations that have affected its ability to produce the intended results. One of the major limitations of the study was the limited time, due to which the researcher relied on the findings of the previous studies to address the research problem. However, the use of primary data and case studies could have enabled the researchers to produce more novel findings on the phenomenon.

5.3. Recommendations and Future Scopes

As established in the previous section that the effectiveness of the study could have been enhanced with the use of primary data and case studies. In this regard, it is recommended to future researchers that intend to conduct an investigation in a similar area and conduct reviews of various case studies of the countries and sectors that have incorporated such models. Future researchers can also conduct interviews with the people associated with such sectors to obtain more novel findings.

6. Declarations

6.1. Author Contributions

Conceptualization, W.M.; methodology, V.P.; validation, L.V.; formal analysis, N.K.; investigation, L.V.; resources, V.P.; data curation, N.K.; writing—original draft preparation, O.S., and A.M.; writing—review and editing, M.V.; visualization, A.K.; supervision, W.M.; project administration, W.M. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

Data sharing is not applicable to this article.

6.3. Funding

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6.4. Conflicts of Interest

The authors declare no conflict of interest.

7. References

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