Lecture Notes on Multidisciplinary Industrial Engineering
Series Editor: J. Paulo Davim

Jiuping Xu · Fang Lee Cooke
Mitsuo Gen · Syed Ejaz Ahmed *Editors*

Proceedings of the Twelfth International Conference on Management Science and Engineering Management

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Lecture Notes on Multidisciplinary Industrial Engineering

Series editor

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Preface

Welcome to the proceedings of the Twelfth International Conference on Management Science and Engineering Management (ICMSEM 2018) held from 1 to 4 August 2018, in Melbourne, Australia. The International Conference on Management Science and Engineering Management is an annual conference organized by the International Society of Management Science and Engineering Management (ISMSEM). The conference aims to foster international research collaborations in Management Science (MS) and Engineering Management (EM) as well as to provide a forum for presenting current research work in the forms of technical sessions. Round-table discussions during the conference period would provide a nice, relaxing and enjoyable atmosphere in which participants can share their academic achievements in MS and EM as well as communicate with others.

The ICMSEM has been held eleven times since 2007 in meeting locations across Asia, Europe and the Americas, and has had a great influence on Management Science and Engineering Management research. In the past eleven years, the ICMSEM has been successfully held in Chengdu, Chongqing, Bangkok, Chungli, Macau, Islamabad, Philadelphia, Lisbon, Karlsruhe, Baku and Kanazawa, each of which attracted some famous researchers in related fields to take part in and make keynote speeches. At the same time, many authors gave excellent presentations and further discussed frontier research in MS and EM. Furthermore, all accepted papers in the proceedings of each International Conference on Management Science and Engineering Management were published by high-level publishing houses, where the 1st, 2nd, 3rd, 4th, 6th, 7th, 8th, 9th and the 10th ICMSEM proceedings have been retrieved by EI or ISTP Compendex and the 12th ICMSEM has been delivered to both ISTP and EI retrieval. Because of the high quality of the research, the ISMSEM Advancement Prize is established to be awarded for papers which focus on innovative practical applications for Management Science and Engineering Management.

Based on the experience of last year's conference in Kanazawa, eight researchers from Azerbaijan, Canada, Japan, Korea, Republic of Moldova, Portugal and the USA made their keynote address presentation about optimization, machine learning, industry 4.0, sustainability and so on. Around 100 authors and some local researchers took part in the conference which generated a heated discussion during the parallel sessions as well as sparked great inspiration for future research. At the opening ceremony, six authors received rewards of ISMSEM Advancement Prize and their excellent papers were selected to report to the attendees. In addition, the solid academic atmosphere and environment of Kanazawa University also made the conference successful and comfortable. Taking this opportunity, we would also like to acknowledge the assistance we received from the International Society of Management Science and Engineering Management, Kanazawa University and Sichuan University for the conference organization.

This year, 136 papers from 19 countries were accepted for presentation or poster display at the conference. These papers were respectively from Australia, Azerbaijan, Bangladesh, Canada, China, Iran, Japan, Korea, the Republic of Moldova, Malaysia, Mexico, Pakistan, Portugal, Spain, Sweden, Thailand, Turkey, the USA and Uzbekistan. Each accepted paper was reviewed by three reviewers, who gave objective and helpful revision advice to the authors where necessary. Therefore, the result has made conference proceedings of very high quality. The papers in the proceedings have been classified into eight sections: Decision Support System, Computing Methodology, Information Technology, Data Analysis and Mining, Operational Management, Project Management, Green Supply Chain and Industry Strategy Management. Besides, the key issues at the twelfth ICMSEM covered many areas of current popularity in Management Science and Engineering Management. To further encourage state-of-the-art research in the field of Management Science and Engineering Management, the ISMSEM Advancement Prize was awarded to the excellent papers at the conference.

We would like to take this opportunity to thank all participants, all of whom worked exceptionally hard to ensure this conference was a success. We want to express our sincere gratitude to the following prestigious academies and institutions for their high-quality papers and great support for the ICMSEM: the Azerbaijan Academy of Sciences, the Moldova Academy of Sciences, Academy of Sciences of the Republic of Uzbekistan, Monash University and Sichuan University. We also appreciate Springer-Verlag for the publication of the proceedings. Meanwhile, we are grateful to Prof. Gary Magee as the General Chair, Prof. Fang Lee Cooke, Prof. Greg Bamber and Prof. George Rivers for their work as the Organizing Committee Chairs. Further, we appreciate the great support received from all members of the Local Committee, International Program Committee Chairs and Members as well as all participants. Finally, we would like to thank all researchers for their excellent conference papers which made the proceedings of our conference more academic and professional.

As MSEM research is in continuous development, many new MSEM development trends have emerged. Our work needs to continue to focus on MSEM so as to encourage greater and more innovative development activity. Next year, we plan to continue the novel and successful ICMSEM and intend to increase our efforts to improve the quality of the proceedings and to recommend more excellent papers for the ISMSEM Advancement Prize. The thirteenth ICMSEM will be hosted in Brock University, Ontario, Canada, in July 2019. Professor Syed Ejaz Ahmed has been nominated as the General Chair for the 2019 ICMSEM, and we believe the next conference will be held successfully and excellently. In the end, we sincerely hope you can submit your new MSEM findings and share your great idea in Ontario, Canada.

Melbourne, Australia
March 2018

Jiuping Xu
Fang Lee Cooke
Mitsuo Gen
Syed Ejaz Ahmed

Organization

ICMSEM 2018 was organized by International Society of Management Science and Engineering Management, Sichuan University (Chengdu, China), Monash University (Melbourne, Australia). It was held in cooperation with Lecture Notes on Multidisciplinary Industrial Engineering (LNMIE) of Springer.

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Chapter 1

The Integration of Various Types of Power Plants Based on Renewable Energy Sources on the Distribution Network

A.Sh.Arifjanov and R.A. Zakhidov

Abstract Distributed generation systems are in most cases represented in the form of autonomous energy centers, since the connection of distributed generators to centralized networks is for the time being limited to the lack or imperfection of the regulatory framework and effective means of managing technological regimes. This report examines the issues of efficient management of the operation modes of various types of power plants based on renewable energy sources in the distribution network. In the report carried out a comparative analysis of the principles of operation and options for connecting to the distribution network of autonomous power plants using various sources of renewable energy. The choice of a rational circuit-based solution for integrating RES into the distribution network was made. When connecting to the distribution network of autonomous power plants based on RES, one of the main tasks to be performed for each hour of the calculation period is the distribution of loads between the generating capacities. The algorithm for solving this task is presented in the report.

Keywords Distributed generation systems · Integration. Power plants · Renewable energy sources · Distribution network · Automation · Circuitry solutions

1.1 Introduction

Trends in the development of the electric power industry in the world are associated not only with the increase in the scale of electricity production in traditional large

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power plants, but also with the increase in the share of distributed generation based on renewable energy sources (RES).

Distributed generation systems are a hybrid power supply systems, combined from various energy sources, are built in close proximity to the consumers and take into account the individual features of this consumers in terms of power and profile to the maximum extent possible. The growth of the share of distributed generation in electric power systems not only has positive aspects, but also creates certain technical problems that are associated with changes in the properties of systems, their control capabilities under normal and emergency conditions.

The management of such power supply systems for which considerable territorial distribution and heterogeneity is characteristic, has the big urgency now. Heterogeneity of system can be connected with use of renewable energy sources, as wind and solar power stations. The main distinguishing feature of energy-generating complexes, based on RES is the stochastic character of the parameters of the primary energy source. This applies largely to helio- and wind power. Therefore, the electrical energy generated from renewable sources creates new problems before the already overloaded network.

The task of modern electrical systems is constant balancing of supply and demand, flexible network management and ensuring optimal levels of energy efficiency. These problems can be solved, but at the same time the dispatching and automatic control of the electric power system becomes more complicated, it is necessary to develop new mathematical models to justify the development of the electric power system and power supply systems, analyze their regimes and manage them.

Most of the autonomous energy systems, using renewable energy sources (RES) that are in operation and offered on the market are technically finished products, adapted for a strictly defined type of power equipment. They do not allow the possibility of expanding their functionality and capacity building by connecting of new sources of generation. This situation is mainly due to the fact that the parameters of electrical power, generated by the source of renewable energy are significantly different in terms of main technical indicators, such as the type of current, frequency and magnitude of the output voltage.

Based on the foregoing, this report examines issues of the integration and effective management of the operation modes of various types of power plants based on renewable energy sources in the distribution network.

The emergence of a large number of combined installations necessitates the systematization of existing devices, which will allow the formation of the most efficient power supply systems. To find the most optimal technological solutions for the combined system, need to analyze each component separately and the system as a whole. Therefore, the report carried out a comparative analysis of the principles of operation and options for connecting to the distribution network of autonomous power plants using various sources of renewable energy. The choice of a rational circuit-based solution for integrating RES into the distribution network was made. The choice of a rational circuit-based solution for integrating RES into the distribution network was made.

When connecting to the distribution network of autonomous power plants based on RES, one of the main tasks to be performed for each hour of the calculation period is the distribution of loads between the generating capacities. The algorithm for solving this task is presented in the report.

1.2 Analysis of the Principles of the Operation of Autonomous Power Plants Based on Different ReS and the Options for Their Connection to the Distribution Network

A feature of the operation of any electric power system is the one-stage production and consumption of electricity. This requires equality of power of energy, generated by the energy plants and of energy, consumed by the consumers . Violation of such equality leads to a change in the network parameters by voltage and frequency, and at large deviation - to the loss of dynamic stability and the disruption of the normal functioning of the system.

There are two possible ways to maintain a continuous in time equality of generated and consumed electricity in power supply systems on based RES. The first way is on the continuously monitor the power consumption and on the appropriate regulation of the power of the sources of electricity so that the equality between the two above mentioned capacities is continuously maintained. The second way is to include in the power grid of the accumulators, that storing electricity at its reduced consumption and after converting feeds the electric grid when a certain level of consumption is exceeded.

A promising option for creating autonomous power supply systems for electricity consumers in decentralized zones is the use of wind-diesel, photo-diesel or wind-photo-diesel power plants. Fig. 1.1 shows a structural diagram of a typical combined power system based on a diesel generator and a wind and photo power station, as well as devices for storing electricity.

In general, such a system consists of the following main blocks:

- Diesel generator plants (DGP);
- Accumulator of electric energy (storage battery);
- Renewable energy sources: solar cells, wind turbines;
- Electric power module - a set of devices that unite various sources of electricity and perform coordination and transformation of the voltages of these sources for the purpose of powering consumers.

The principle of operation of an autonomous power plant is as follows (Fig. 1.2) [3]: (1) In order to ensure high-energy efficiency of the autonomous power supply system, the energy generated by the primary energy source should be directly delivered to the consumer (Path 3). (2) In periods of excessive energy generation, the energy should be stored by the accumulation system (Path 1). (3) If there is a shortage in the energy generated by a primary source, the accumulated energy from secondary sources should be delivered to the consumer, covering the existing shortage (Path 2).

The effective control system of the station should provide not only a strategy of controlling of the power of the DGS, WPP and the PVP, but also synchronization of the start-up of the units and their further synchronous operation.

In power supply systems with RES, as a rule, there are three methods of controlling the flow of energy: on the basis of the discharge of surplus energy, the accumulation of energy and the change in the load (Fig. 1.3) [1].

Due to the non-stationary nature of the generation process by RES, the practical implementation of these management methods is a serious problem.

Consider options for connecting RES-based power plants to the distribution network in combined energy systems. There are different variants of conjugation of diesel generator plants (DGP), wind power plants (WPP) and photovoltaic plants (PVP), working to general consumer, which can significantly differ by the composition of the used electrical equipment and by the technical and economic characteristics.

At present, several types of combined systems based on RES have been developed: - alternating current -alternating current (AC/AC) power supply system; - di-

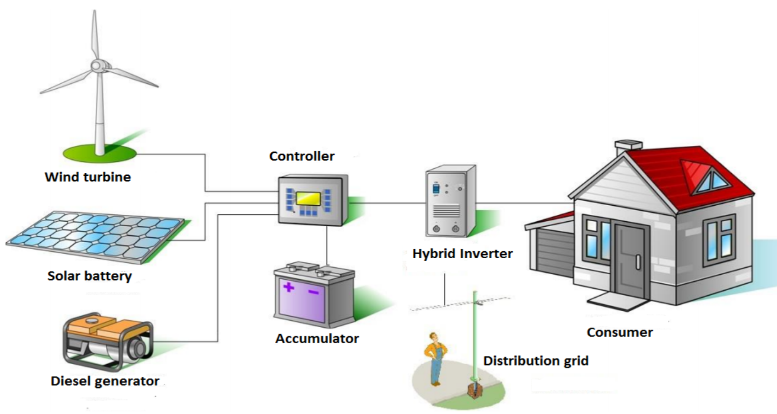


Fig. 1.1 Structural diagram of a combined power system based on a diesel generator set, an electric energy storage and renewable energy sources

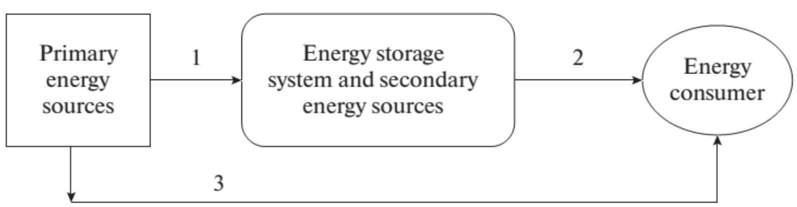


Fig. 1.2 Interaction of the main components of the autonomous power supply system

rect current - direct current (DC/DC) power supply system; - systems with mixed connection.

Combined AC power systems can be divided into two categories: centralized and decentralized (distributed). In the centralized combined AC power system, all the elements making up the system are connected to the main AC bus in front of the consumer. This configuration is shown in Fig. 1.4a. In the Fig. 1.4a, the wind turbine and the diesel generator generate an alternating current, so they can be directly connected to the main AC bus or AC / AC converters. The photovoltaic module produces a direct current (DC), hence the inverter (voltage converter) must be used before connecting to the main AC bus. For batteries with a DC stream, a bi-directional inverter must be used.

In a decentralized combined AC power system, all elements are distributed or decentralized. The elements forming the system are not connected to the backbone AC bus, some or all of the elements are individually associated with the consumer (Fig. 1.4b).

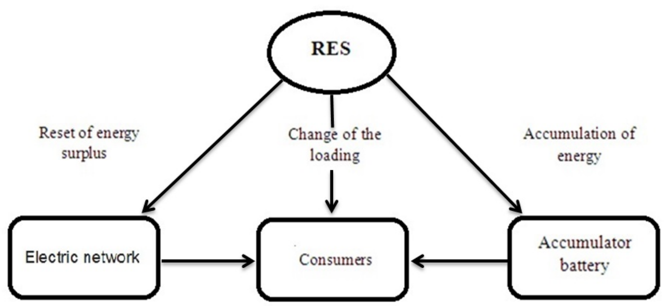
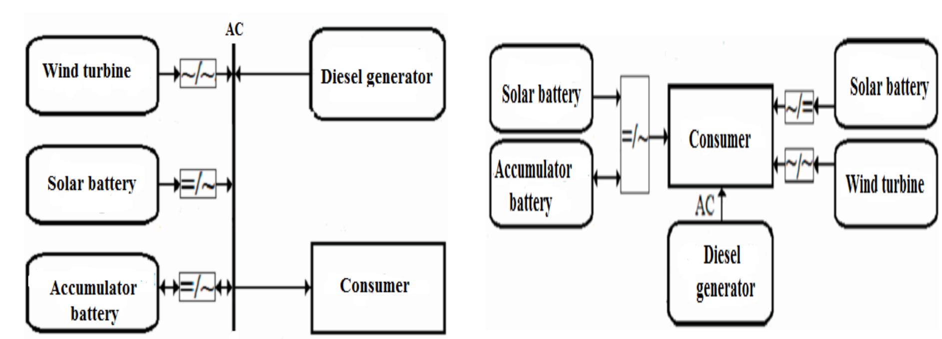


Fig. 1.3 Scheme of energy flow control methods from RES to consumers



a) b)

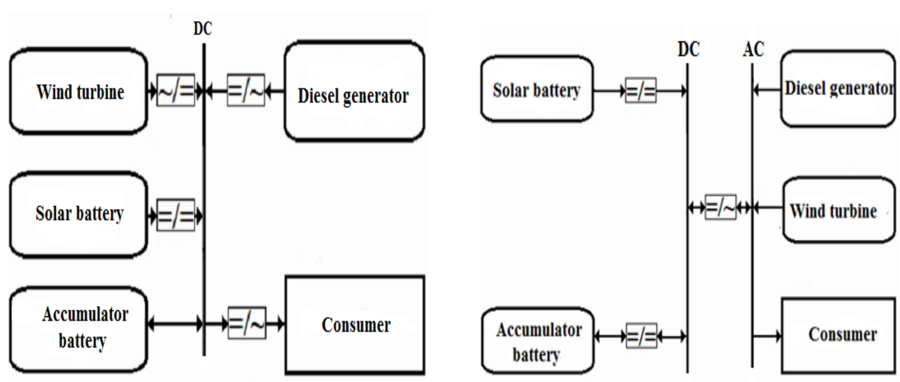
Fig. 1.4 C Centralized (a) and decentralized (b) combined AC power system

In a decentralized system, energy sources should not be connected to one common bus, as in the previous case. With this configuration, the energy sources need not be located close to each other, since each source of the system is connected to the consumer separately. The DC obtained from the photovoltaic cells and accumulator batteries must be converted to alternating current (AC) by the respective inverters in front of the consumer. This type of system is advantageous in that various sources can be located remotely from each other, so that more convenient locations can be selected (places with greater illumination for photovoltaic cells or more windy for wind turbines). In addition, this system has drawbacks in terms of control difficulties.

When comparing centralized and decentralized systems, the advantage of centralized combined power supply systems is obvious, since they can be controlled more easily and conveniently.

In a centralized combined DC system (Fig. 1.5a), all elements are connected to the main DC bus directly in front of the user. Communication with the AC bus is made through the main inverter. Since the power sources are connected to the DC bus, therefore, the wind turbine and the diesel generator need on AC / DC converters before they are connected to the main bus. The AC consumer is connected to the main DC bus through the main DC / AC inverter.

On the Fig. 1.5b shows a widespread version of a hybrid power plant scheme using RES, where sources are connected directly to the distribution network without intermediate electricity conversion.



a) b)

Fig. 1.5 Centralized combined DC system (a) and combined mixed power system (b)

1.3 Circuitry Solutions for Connecting Res-Based Power Plants to the Distribution Network

The autonomous power supply system presented in Fig. 1.6 is simple to implement, which makes it easy to scale it by installing, for example, several wind turbines. Due to the absence of additional transformations of electric power, is ensured a high efficiency factor of the energy system as a whole . However, this method of building a system requires the presence of specified, identical and constant values of the voltage and frequency of the network at the outputs of electrical generators. This requires the use of a wind turbine with complex systems for aerodynamic stabilization of the rotor speed or the use of an asynchronous machine with a phase rotor with its appropriate control from a network inverter [2]. Such wind turbines are suitable for large wind energy, but they find extremely limited application in the construction of small energy systems due to the high cost of plants.

1 - Wind power plant; 2 - wind turbine; 3- reducer-multiplier; 4, 14 - synchronous electric machine generators; 5, 15 - devices of smooth start-up; 6, 16 - regulators of excitation current of synchronous generators; 7 - block of ballast loads; 8 - reactive power compensator; 9 - photoelectric installation; 10-solar panel; 11 - impulse con-

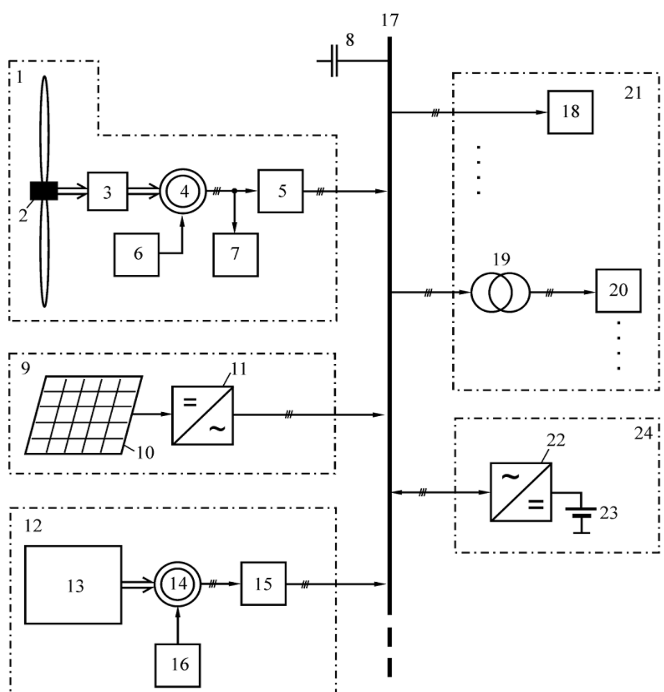


Fig. 1.6 Scheme of a hybrid power plant with direct connection of generating units to the distribution network

verter of a direct voltage in variable (inverter); 12 - diesel generator; 13 - the diesel engine; 17 - the bus of an alternating current 220/380 V, 50 Hz; 18 - consumers 220/380 V; 19 - power step-up transformer; 20 - consumers of 6 or 10 kV; 21 - an object of decentralized power supply; 22 - bi-directional converter of AC voltage to DC; 23 - the unit of accumulator batteries; 24 - buffer storage of electricity.

These shortcomings are absent in the coupling variant according to the scheme shown in Fig. 1.7.

Despite the more complex structure of the energy complex, this scheme has the following advantages in comparison with that considered in Fig. 1.6 [2]:

(1) In this case, there is no need to reconcile the operation modes of the DPS, W-PP and the PVP, which allows to control these units based on the required optimality criteria.

(2) The system is easy to scale and simply enough to solve the problem of electromagnetic compatibility.

(3) Due to the consumers' power supply from a common autonomous inverter, high quality of the supplied electric energy is ensured.

(4) The schemes of the converters for connecting the PVP and the energy storage device have been greatly simplified, and it is also possible to include in the system a wind turbine wich variable-frequence of rotation (via a controlled rectifier).

This variant of hybrid energy complexes has found wide application at small and medium capacities (1 - 100 kW).

1 - Wind power plant; 2 - wind turbine; 3, 11, 15 - synchronous electromachine generators; 4, 12 - controlled rectifiers; 5 - block of ballast loads; 6 - photoelectric installation; 7- solar panel; 8 - voltage converter; 9, 13 - diesel generators; 16 - soft starter; 17 - excitation current controller; 18 - direct current bus; 19 - voltage inverter; 20 - buffer storage of electricity; 21 - bi-directional pulse converter; 22 - battery pack; 23 - the bus of an alternating current 220/380 V, 50 Hz; 24 - consumers 220/380 V; 25 - power step-up transformer; 26 - consumers of 6 or 10 kV; 27 - an object of decentralized electricity supply.

A variant of a hybrid power plant based on conjugation of power plants by means of an auxiliary bus operating at a high frequency (unit kHz) is shown in Fig. 1.8.

This method is mainly used in creating power supply networks for air and space vehicles. It allows to minimize the number of reactive elements in the system, to reduce the weight and dimensions and, accordingly, to reduce the cost. But because of the geometric disconnection of individual aggregates (DPS, WPP , PVP and etc.), at using this scheme, arise a number of problems, related to power losses in the auxiliary network, electromagnetic compatibility, etc. [2].

A comparative analysis of the schemes of autonomous power plants has shown that the most promising variant of conjugation of different types of power plants in one energy system is the use of an intermediate DC insert. In this case, the hybrid power complex is built on an aggregate principle, easily scaled and, if necessary, rearranged. In addition, it is possible to unify the structure and construction of electronic power converters. Using the modular principle of their construction, it is simpler to develop a line of converters for the model row of capacities. The use of DC insertion makes it possible to more simply summarize and distribute energy flows from generating sources and implement effective control algorithms for this process.

1 - Wind power plant; 2 - wind turbine; 3, 11 - synchronous electro-machine generators; 4, 12, 14 - static frequency converters; 5 - block of ballistic loads; 6 - photoelectric installation; 7- solar panel; 8 - voltage converter; 9 - diesel generators; 10 - diesel engine; 13 - high frequency AC bus; 15 - buffer storage of electricity; 16 - bidirectional pulse converter; 17 - battery pack; 18 - the bus of an alternating current 220/380 V, 50 Hz; 19 - consumers 220/380 V; 20 - power step-up transformer; 26 - consumers of 6 or 10 kV; 21 - consumers of 6 or 10 kV; 22 - the object of decentralized power supply.

The block diagram of the autonomous power supply system with a DC insert is shown in Fig. 1.9. This system consists of separate generating power units PU1, PU2, $\cdots$, PUn, the number of which in the general case can be arbitrary. Each unit includes a corresponding power unit PP1, PP2, $\cdots$, PPn , built on one or another physical principle, and a controlled static converter SC1, SC2, $\cdots$, SCn . As power plants can be used wind turbines, solar modules and diesel generators, working at both constant and variable frequency of rotation of the shaft of the diesel engine. For each type of power plant the controlled converter - own, for example, for wind turbines and diesel generator use controlled boosting rectifier, and for photovoltaic modules use controlled converter.

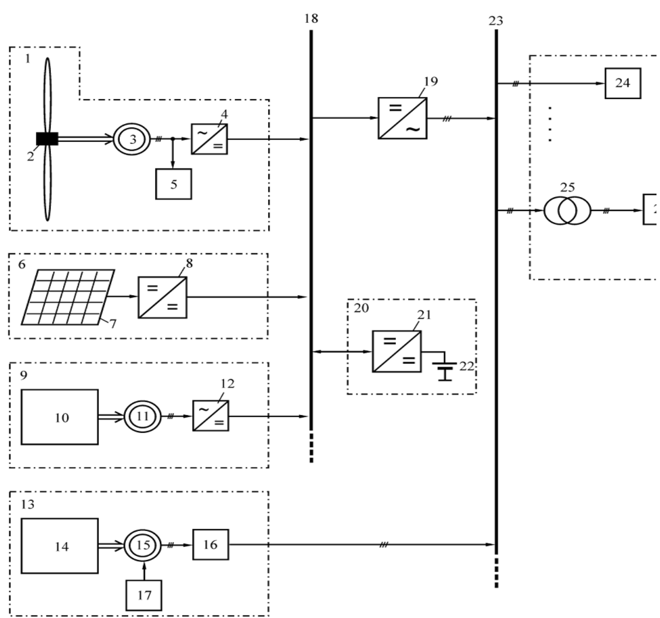


Fig. 1.7 The scheme of a hybrid power plant with connection of generating units to an intermediate DC bus (and with a mixed connection)

An important advantage of the proposed scheme of the hybrid power plant is the possibility of a significant expansion of the functions of the buffer energy storage system when input signals to the control system are inputted about the current wind speeds (from the wind turbine) and the intensity of solar radiation (from PVP). In this case, the control system of buffer storage of power outputs the output control signals to the power unit converters providing the mode of selection of the maximum power from the power plants. When using diesel generator of the “inverter” type as part of the power complex, from the control system of the buffer storage of power a control signal is sent to the executive mechanism for controlling the position of the rod of fuel pump , providing optimization of the diesel generator operation modes by the criterion of minimum fuel consumption.

This set of functions can be implemented by installing the corresponding additional expansion modules into the buffer storage system (if there is a technical capability to control the output of the generator power units). Due to additional modules, the system receives and processes information about environmental conditions from the meteorological complex; calculates in real time the optimal values of the current loads for each generating power unit, based on the principle of maximum power takeoff and generates control actions for each converter of the generating source.

Thus, the scheme of an autonomous power station built according to the principles described above has the following possibilities:

- inclusion in the system of any autonomous power plant irrespective of the installed power equipment;

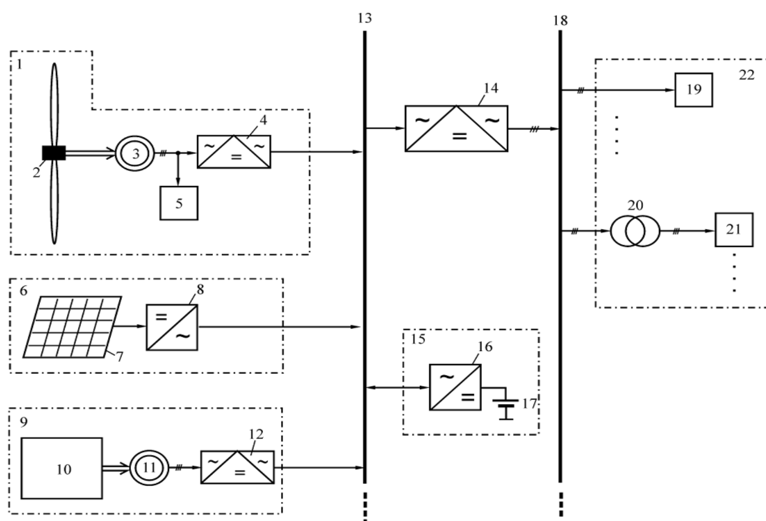


Fig. 1.8 The scheme of a hybrid power plant with the connection of generating plants through a high-frequency bus of alternating current

-program configuration of the energy storage system for a specific power complex by connecting to a BSE control system of a personal computer when performing this operation;

- management of energy flows not only between the system and BSE, but also between all power plants and the load (if the installed equipment allows);

-effective use of the potential of the wind plant by installing additional modules to collect information on environmental conditions and development of control actions for the purpose of managing the power plants of the complex.

The main distinguishing feature of energy-generating complexes based on RES is the stochastic character of the parameters of the primary energy source. This applies to a greater extent to helio- and wind power.

Obviously, in this case, it is necessary to make maximum use of renewable sources in all modes of operation of the power system, in conditions of randomly varying solar activity, wind speed and variable electrical loads, providing a reduction in the load of the supply line.

1.4 Algorithm of the Distribution of Loads between the Generating Aggregates

When connecting to the distribution network of autonomous power plants based on RES, one of the main tasks to be performed for each hour of the calculation period is

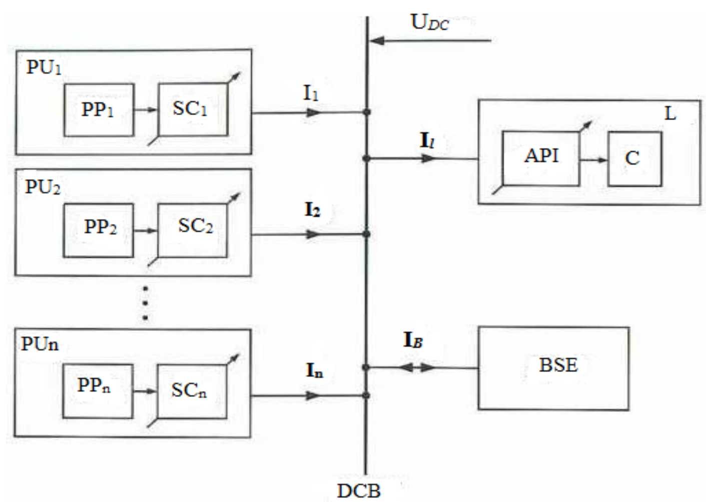


Fig. 1.9 Structural diagram of the system of autonomous power supply with DC insert. $I_1, \cdots, I_n$ - currents of power units; I_l - load current; I_B - current of the buffer storage of energy; U_{DC} is the voltage on the DC bus

the distribution of loads between the generating aggregates. The following approach is used to solve this problem: (1) It is determined (based on climatic conditions and astronomical parameters of the Sun) the potentially possible generation of power by PVP and WPP (at their specified installed capacity).

(2) It is determined losses of active power in the transmission of potentially possible generated energy by PVP and WPP to the consumer.

(3) If the summary power of generated by PVP and WPP energy is not less than the load of the consumer, the all it is covered by renewable energy sources.

(4) If there is surplus of power, then it is transmitted to charge of the accumulators. In the case when the accumulators have already been fully charged, then on the corresponding amount reduces the power of RES. Initially regulated of wind turbine (as the most wearing), and then PVP.

(5) If the total capacity of renewable energy sources is less than the load of consumers, the lack of capacity is covered by the accumulators.

(6) If the accumulators are discharged (the charge 30% of the nominal value), then the DPS is switched on. It turns on at full power and turns off when the storage battery reaches a certain threshold value (50% of the nominal value).

(7) If the power of the DPS in conjunction with RES with a discharged accumulator is less than the load of the consumer, then there is a shortage of electricity.

1.5 Conclusion

A comparative analysis of the schemes of autonomous power plants has shown that the most promising variant of conjugation of different types of power plants in one energy system is the use of an intermediate DC insert. In this case, the hybrid power complex is built on an aggregate principle, easily scaled and, if necessary, rearranged. In addition, it is possible to unify the structure and construction of electronic power converters. Using the modular principle of their construction, it is simpler to develop a line of converters for the model row of capacities. The use of DC insertion makes it possible to more simply summarize and distribute energy flows from generating sources and implement effective control algorithms for this process.

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