6/2023, noyabr-dekabr (№ 00068)

EFFICIENT INFORMATION FLOW PROCESSING FOR MONITORING AND CONTROLLING SMART GRID SYSTEMS

Mirzaakhmedov Dilmurod Miradilovich
Senior lecturer of Tashkent State University of Economics echo19_87@mail.ru
https://orcid.org/0000-0002-1359-8668
DOI: *https://doi.org/10.55439/EIT/vol11_iss6/a21*

Abstract
The paper proposes an approach to processing information flows under the monitoring and control of smart grid regimes, based on the creation of a new information technology infrastructure (IT infrastructure) under the automated control of intelligent energy systems, designed to process the information flows and improve their quality. A two level information technology is offered to support decision making in controlling smart grid regimes. This technology integrates intelligent tools for situation analysis and software systems for modeling and regime control. The use of IT infrastructure allows to create a single information space, including data and knowledge as well as a set of mathematical models and methods for solving electrical power engineering problems under the active adaptive management.
Keywords: intelligent power system; IT infrastructure; information stream; mode control; models; information quality.

AQILLI TARMOK REJIMLARINI KUZATISH VA BOSHQARISHDA AXBOROT OQIMLARINI QAYTA ISHLASH

Mirzaahmedov Dilmurod Miradilovich
Toshkent davlat iqtisodiyot universiteti katta o'qituvchisi

Annotatsiya
Mazkur maqola aqlli tarmoq rejimlarini kuzatish va boshqarish ostida axborot oqimlarini qayta ishlash yondashuvini taklif etadi, bu yondashuv yangi axborot texnologiyalari infratuzilmasini (IT infratuzilmasi) yaratish asosida qurilgan bo'lib, u aqlli energetika tizimlarining avtomatlashtirilgan boshqaruv ostida mo'ljallangan, axborot oqimlarini qayta ishlash va ularning sifatini yaxshilashga qaratilgan. Qaror qabul qilishni qo'llab-quvvatlash uchun ikki darajali axborot texnologiyasi taklif etiladi, bu texnologiya vaziyatni tahlil qilish uchun aqlli vositalarni va rejimni boshqarish uchun dasturiy tizimlarni birlashtiradi. IT infratuzilmasidan foydalanish orqali ma'lumotlar va bilimlar hamda elektr energetika muammolarini hal qilish uchun matematik modellar va usullar to'plamini o'z ichiga olgan yagona axborot maydonini yaratish imkonini beradi, bu esa faol moslashuvchan boshqaruv ostida amalga oshiriladi.
Kalit so'zlar: aqlli energetika tizimi; IT infratuzilmasi; axborot oqimi; rejimni boshqarish; modellar; axborot sifati.

ОБРАБОТКА ИНФОРМАЦИОННЫХ ПОТОКОВ ПРИ МОНИТОРИНГЕ И УПРАВЛЕНИИ РЕЖИМАМИ УМНОЙ СЕТИ

Мирзаахмедов Дилмурод Мирадилович
Ташкентского государственного экономического университета

Аннотация
В статье предлагается подход к обработке информационных потоков при мониторинге и управлении режимами умной сети, основанный на создании новой информационной технологической инфраструктуры (IT-инфраструктуры) под автоматизированным контролем интеллектуальных энергетических систем, предназначенной для обработки информационных потоков и улучшения их качества. Предлагается двухуровневая информационная технология для поддержки принятия решений в управлении режимами умной сети. Эта технология интегрирует интеллектуальные инструменты для анализа ситуации и программные системы для моделирования и контроля режима. Использование IT-инфраструктуры позволяет создать единое информационное пространство, включающее данные и знания, а также набор математических моделей и методов для решения проблем электроэнергетики под активным адаптивным управлением.
Ключевые слова: интеллектуальная энергетическая система; IT-инфраструктура; информационный поток; контроль режима; модели; качество информации.

Introduction

Currently, there is an active development of a direction in the world called Smart Grid (intelligent energy systems or intelligent electrical networks) - electrical energy systems using new technologies in both power equipment and information technology, aimed at improving technical and economic performance. The focus of specialists is primarily on improving the technological infrastructure of the energy sector, without which the implementation of modern information technologies is impossible. At the same time, the development of a methodology and new information and telecommunication technologies is necessary, which should become the basis for smart [8] energy systems. The paper proposes an approach to processing information flows in the monitoring and management of modes of intelligent energy systems, which involves the integration of information and mathematical technologies and the use of international data standards.

Literature Analysis

Voropai, N.I. (2019): Voropai discusses the concept, state, and prospects of intelligent power systems, emphasizing the need for advanced technologies to improve technical and economic performance. He identifies a gap in the development of a methodological framework that integrates modern information technologies into smart energy systems.

Massel, L.V. (2016): Massel explores the challenges of building intelligent and software components of Smart Grid. He highlights the limitations of current IT offerings in this segment and the reliance on expensive foreign developments, suggesting the need for high-quality domestic developments and a reduction in dependency on foreign IT solutions for energy cybersecurity.

Gurina, L.A. (2016): Gurina's work focuses on improving the quality of information flows for mode management in electrical networks. She presents technological solutions to enhance information flow quality, addressing the challenges of managing data streams in smart grids.

Gamm, A., Grishin, Y., Kolosok, I. (2017): This study discusses reducing the risk of blackouts through improved state estimation based on SCADA and PMU data. It contributes to understanding the importance of reliable data processing and risk management in smart grid systems.

Kobets, B.B., Volkova, I.O. (2017): Kobets and Volkova discuss the innovative development of power engineering based on the Smart Grid concept. They provide insights into how innovative technologies and concepts can transform power systems, offering a perspective on future developments in smart grids.

Massel, L.V., Abidov, D.A., Mirzaaxmedov, D. (2022): In their recent work, these authors present an analytical model for assessing the reliability of the functioning of adaptive switching nodes. Their focus on the reliability aspect adds a crucial dimension to the discussion of efficient information processing in smart grids.

In contrast to the works reviewed, this article proposes a unique two-level information technology approach that integrates intelligent tools for situation analysis with software systems for modeling and regime control. It emphasizes the creation of a unified IT infrastructure to enable efficient information processing, a gap not fully addressed in the existing literature. This approach aims to enhance decision-making in controlling smart grid regimes, contributing a novel perspective to the field.

Methodology

The methodology begins with the development of a new IT infrastructure for Intelligent Energy Systems (IES), including intelligent, information, computing, and telecommunications infrastructures.

This infrastructure aims to create a unified information space to enable efficient information processing in smart grids.

Two-Level Information Technology:

A two-level information technology approach is proposed.

At the first level, intelligent technologies are used for qualitative analysis of situations arising in IES.

The second level involves numerical calculations for situations determined by the qualitative analysis, using adapted software complexes.

Application of CIM and CEP Models:

The Common Information Model (CIM) and Complex Event Processing (CEP) models are integrated into the methodology.

These models are used for real-time processing of event streams and building complex energy data models.

Classification of Information and Mathematical Models:

Information on power system mode parameters is classified into deterministic, probabilistic, fuzzy, and interval-based groups.

Different mathematical models are applied depending on the type of information, under conditions of active-adaptive control.

Quality Assessment of Information Flows:

A technology for improving the quality of information flows based on fuzzy set theory is implemented.

The quality of measurement information is determined using a specific quality criterion, and information is classified accordingly.

Modeling and Simulation:

Modeling of power system operating modes, processes of changing operating parameters, and state evaluation of the power system.

Simulation tests are conducted to assess the robustness of models in active-adaptive power system control.

Empirical Validation:

The proposed models and methodologies are validated through empirical case studies and real-world applications in smart grid systems.

The challenges of creating a Smart Grid. Smart Grid includes all the main traditional components of power systems: generation, transmission and conversion of electrical energy, as well as consumers, but with a qualitatively new technological level and characterized by close interconnection. Smart Grid should provide an increase in the reliability and cost-effectiveness of electricity production based on the use of modern high-intelligence means of control and management, integration of renewable energy sources, as well as distributed generation and energy storage, large-scale monitoring of modes and their management using new tools and technologies [1].

The common problems of creating intelligent energy systems (IES) from the perspective of information and communication technologies are as follows: 1) the need to develop information and communication technologies that allow for the creation of qualitatively new monitoring and control systems for energy systems; 2) a limited range of offerings in this segment from IT vendors: solutions from foreign developers are quite expensive, there are not enough high-quality domestic developments, or they simply do not exist. In addition, reliance on foreign developers is not welcomed, as dependence on foreign firms is one of the threats to the cybersecurity of IES [2].

At the current stage of electrification system intelligence, the most important issues are the development of information technology infrastructure (IT infrastructure) in the automated control systems (ACS), ensuring the construction of a multi-level management system that takes into account the reliability, economy, and efficiency of power system operation. In addition, the implementation of new systems for collecting, transmitting, and processing streams of information will require the development of technologies and methods for modeling the processes and events under study when managing the power system. Therefore, the following tasks become relevant: 1) collection, transmission, and processing of data streams; 2) development of new generation software complexes (distributed, exchanging information or using common information resources); 3) development of intelligent decision support components for power system operation [3].

IT infrastructure for power systems. To create and develop power systems, based on the experience of the Institute of Energy Systems named after Chernyshevsky of the Siberian Branch of the Russian Academy of Sciences [4-5], it is proposed to identify the following main components in the IT infrastructure: intelligent infrastructure; information infrastructure; computing infrastructure; telecommunications infrastructure. The telecommunications infrastructure is built on generally accepted principles (for example, similar to the telecommunications infrastructure of the data transmission network of the Siberian Branch of the Russian Academy of Sciences), taking into account the requirements of computer and information security. The intelligent infrastructure includes intelligent components (for example, the aforementioned intelligent decision support components for power system operation). The information infrastructure includes technologies and tools for describing, storing and processing data. The core of the information infrastructure is the Repository, which stores metadata (descriptions of data flows, databases, data models, etc.). The computing infrastructure integrates software complexes (for example, for modeling [14] and managing power system operation). Automated energy management systems can also be classified under this infrastructure.

"The elements of the IT infrastructure of dispatch control include:

Information collection and transmission system (ICTS);

Dispatch and technological management communication network;

Supervisory Control and Data Acquisition System (SCADA)[7];

Common Information Model (CIM);

Information display system;

Energy Management System (EMS);

Market Management System (MMS);

Transmission and Distribution Management System (DMS)."

The proposed approach to processing information flows for monitoring and managing modes of power systems IES.

The term "information flow" refers to the set of measured process variables over a certain period of time [6]. When monitoring and automating the modes of the power system, analysis and processing of information flows are essential.

The CEP (Complex Event Processing) model [9] is proposed to be used for real-time processing of a set of events from various sources (event streams) with the aim of detecting significant events based on one or several event streams, or identifying a series of events over a certain period of time. The CIM (Common Information Model) model, based on the ODM and CIM data formats, allows building models of any complexity, which can then be converted into any well-known energy data format or into any new data format using additionally connected modules. ODM (Open Model for Exchanging Power System Simulation Data) is an open model for exchanging data in power system modeling [14]. ODM is an international open data exchange standard for modeling and calculating energy systems, supporting dynamic calculations [10-11].

From the above, it is evident that there is a need for real-time processing of large volumes of information of varying quality and the formation of such information flows that would ensure the required accuracy of solving operational tasks. The scheme of processing information flows during monitoring and control of modes in IES (Integrated Energy System) is presented in Fig. 1.

Two-level technology for decision support in managing operating modes in Integrated Energy Systems.

The proposed two-level information technology, shown in Fig. 2, in which:

on the first (upper) level, using intelligent technologies, a qualitative analysis of situations arising in the IES (Integrated Energy System) will be performed;

on the second level, using adapted software complexes, numerical calculations are carried out for situations determined with consideration of the qualitative analysis results.

As intellectual decision-making support technologies at the qualitative analysis stage, it is proposed to primarily use ontological, cognitive, and event modeling technologies (these technologies have been tested in the Energy Systems Institute of the Russian Academy of

Sciences for energy security research, scientific prototypes of instrumental tools are available, integrated within the intellectual IT environment) [12-13]. In the future, intelligent technologies can be supplemented with artificial neural network technologies, fuzzy sets, genetic algorithms, and wavelet analysis, depending on the properties of information flows [14].

Classification of information and mathematical models for its description.

Information on the parameters of the mode is divided in [6] into 4 groups: deterministic, probabilistic, fuzzy, and interval-based – for the possible application of various mathematical models under the conditions of active-adaptive control of the power system (Fig. 3). Deterministic information is based on regular cause-and-effect relationships and is conditioned by numerically unambiguous assignments of equipment types, their composition, and nominal parameters. Probabilistic

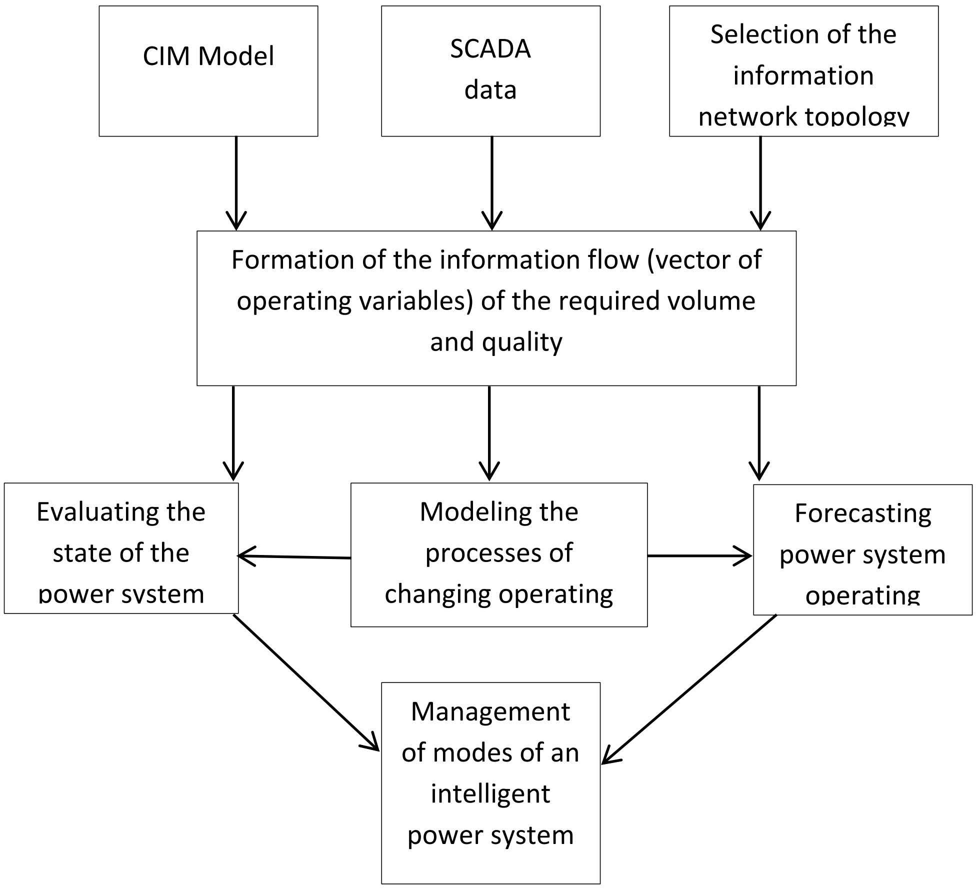

Fig. 1. General scheme of information processing flows in monitoring and management of modes of the intelligent power system.

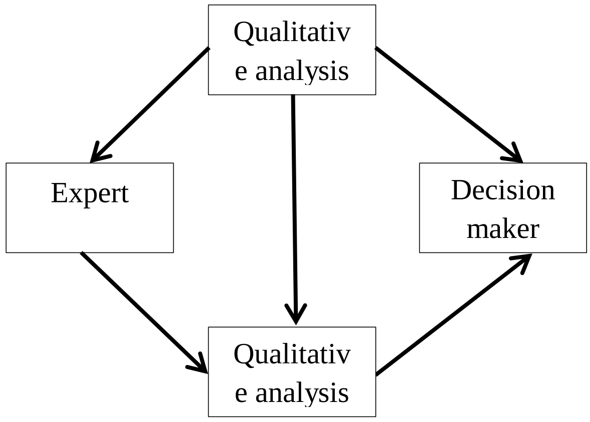

Fig. 2. Two-level decision support information technology for managing modes in the Integrated Energy System (IES)

Information describes the stochastic nature of mode parameter changes, as well as the set of network elements corresponding to a given mode. Fuzzy information – the values of mode parameters are described by membership functions of a fuzzy subset of their variation. Interval information is typical for cases when only an approximate range of mode parameter changes is known, formed by their minimum and maximum possible values.

As an example, the technology for improving the quality of information flows based on fuzzy set theory is considered (Fig. 4).

The quality of measurement information is determined using a quality criterion [4]. To do this, the entire information base is represented in the form of four sets:"

A_I– the set of reliable values;

A_{II}– the set corresponding to the full volume of information;

A_{III} – the set corresponding to an incomplete volume of information;

A_{IV} – the set of unreliable values.

To determine the completeness and reliability of information, ensuring the required accuracy of mode management tasks, a threshold level α is introduced for fuzzy regions, the quantitative value of which corresponds to the optimal parameters of information quality:

$$\alpha = \frac{1}{lnN * \sum_{i=1}^{N} \mu_{A_i}\sim(A_i)} [\sum_{i=1}^{N} \mu_{A_i}\sim(A_i) ln \sum_{i=1}^{N} \mu_{A_i}\sim(A_i) - \sum_{i=1}^{N} \mu_{A_i}\sim(A_i)], (1)$$

where $\mu_{A_i}\sim(A_i)$ - membership function for the i-th of the above sets.

The set of α-level is described as $\tilde{A}_\alpha$ = $\{\frac{\tilde{A}_i}{\tilde{A}_i} \in A, \mu_{A_i}\sim(A_i) \geq \alpha$ where

$$A_i \in A, \forall\alpha \in [0,1].$$

The proposed quality criterion allows classifying information and applying those mathematical models that provide the highest accuracy in its description.

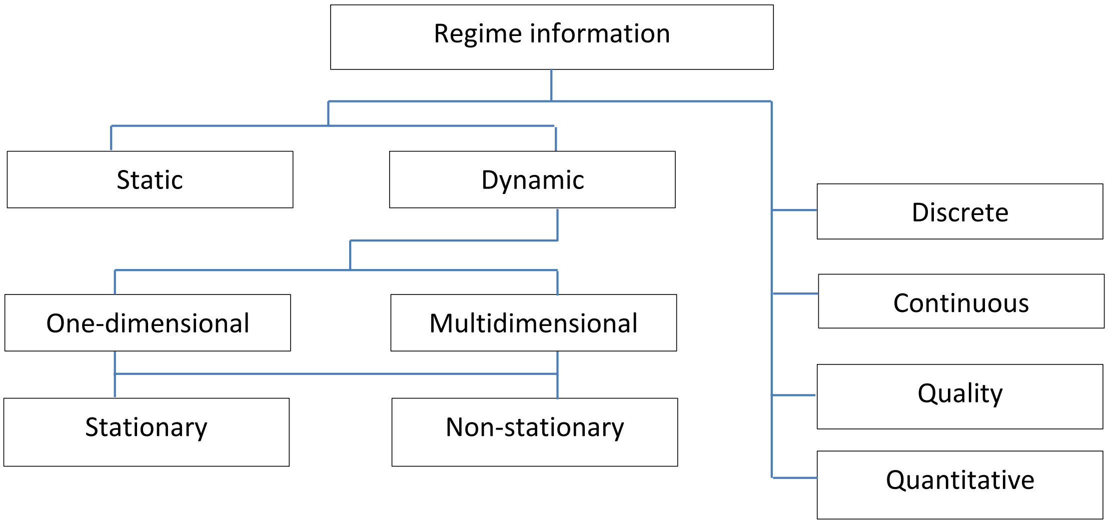

Fig. 3. Classification of mathematical models

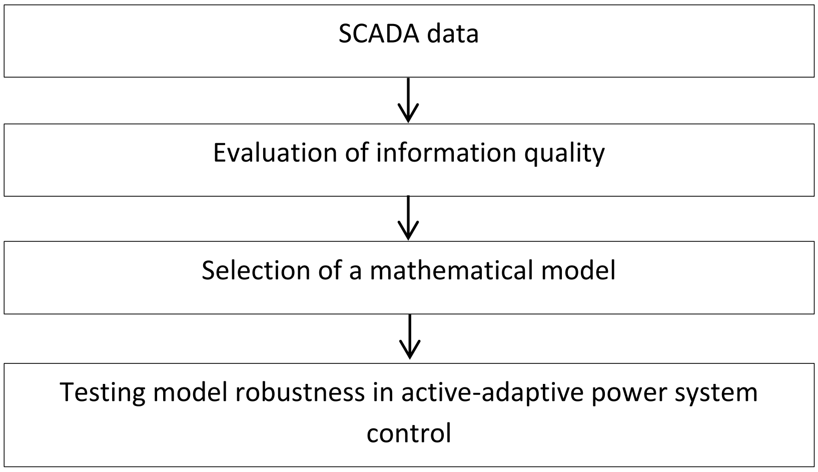

Fig. 4. Technology for improving the quality of information flows

Conclusion. In this work, an approach to the development of a new IT infrastructure for Intelligent Energy Systems (IES) is proposed, which includes a unified information space and, thus, creates prerequisites for constructing a multi-level management system for intelligent power systems. It is proposed to expand the class of models used in solving power engineering problems by including CEP and CIM models.

The proposed two-level information technology for decision-making support in IES mode management is considered, integrating intelligent technologies and software packages for modeling and mode management. A new scheme for processing information flows of varying degrees of completeness and reliability in the management of power systems modes is presented. A classification of information types about mode parameters is provided, and the feasibility of using different mathematical models depending on the quality of mode information is demonstrated.

List of used literature

1.Voropai N.I. Intelligent power systems: concept, state, prospects // Automation and IT in power engineering. 2019. No.3. P. 11–16.

2.Massel L.V. The problem of building intelligent and software components of Smart Grid and the approach to its solution based on agent technology // Materials of the XL International Conference "Information Technologies in Science, Education, Telecommunications and Business". Supplement to the journal "Open Education". Ukraine, Crimea, 2016. P.22 – 25.

3.Massel L.V. Intellectualization of decision-making support in modeling and managing regimes in Smart Grid // Intellectualization of information processing: proceedings of the 9th International Conference. Montenegro, Budva, 2016. P. 692–695.

4.Voropai N.I., Massel L.V. IT infrastructure of system research in power engineering and provision of IT services // Proceedings of the Academy of Sciences. Energy. 2015. No.3. P. 86–93.

5.Massel L.V., Boldyrev E.A., Makagonova N.N. et al. IT infrastructure of scientific research: methodological approach and implementation // Computational Technologies. 2018. Vol.11. P.59–67.

6.Gurina L.A. Technology for improving the quality of information flows for mode management in electrical networks // Information and mathematical technologies in science and management: proceedings of the XVI Baikal All-Russian Conference. Irkutsk: ISEM RAS, 2016. Part III. P. 103–109.

7.Gamm A., Grishin Y, Kolosok I. Reducing the risk of blackouts through improved EPS state estimation based on the SCADA and PMU data // Liberalization and Modernization of Power Systems: Risk Assessment and Optimization for Asset Management: Proc. of the Int. Workshop. Irkutsk, Russia, 14-18 Aug. 2017. P. 167-173.

8.Voropai N.I. Smart Grid: myths, reality, prospects // Energy Policy. 2016. No.2. P.9 - 14.

9.Kobets B.B., Volkova I.O. Innovative development of power engineering based on the Smart Grid concept. M.: IAC Energy, 2017. 208 p.

10.Massel L.V., Podkamenny D.V., Bakhvalov K.S. Open integration environment InterPSS for solving power tasks and its adaptation for reengineering of the software "DAKAR" // Problems of reliability of existing and prospective power systems and methods of their solution: materials of the International scientific seminar named after Yu.N. Rudenko "Methodological issues of research of reliability of large power systems". Ivanovo: Reshma. 2018. Issue.62. P. 431– 437.

11.Massel L.V., Bakhvalov K.S. Open integration environment InterPSS as a basis of IT infrastructure of Smart Grid // Bulletin of IrGTU. 2012. No.7 (67). P. 6–10.

12.Massel L.V. Application of ontological, cognitive and event modeling for analysis of development and consequences of emergencies in power engineering // Problems of safety and emergencies. 2018. No.2. P. 34–43.

13.Massel A.G., Massel L.V., Arshinsky V.L. Intelligent IT environment for decision-making support in research and ensuring energy security of Russia and its regions // Intellectualization of information processing: proceedings of the 9th International Conference.

14. Abdujabbor Abidov, Dilmurod Mirzaaxmedov and Dilmurod Rasulev Analytical model for assessing the reliability of the functioning of the adaptive switching node // 22nd International Conference, NEW2AN 2022 Tashkent, Uzbekistan, December 15–16, 2022 Proceedings