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CLASSIFICATION OF WIND ENERGY CONVERSION SYSTEMS

The article analyzes the role, place and features of functioning of wind power plants. Several variants of generators and schemes for converting wind energy into electrical energy are given. A detailed analysis of existing wind units is provided. Recommendations are given for improving the reliability of wind power installations in smart grids.

Keywords: wind farms, wind turbines, fixed speed wind turbines, asynchronous generator wind turbine, with dual power supply, variable.

INTRODUCTION

Kazakhstan is exceptionally rich in wind resources. About 50 % of the territory of Kazakhstan has an average annual wind speed of 4-5 m/s, and a number of districts have a wind speed of 6 m/s or more, which determines very good prospects for the use of wind energy. According to some data the theoretical wind potential of Kazakhstan is about 1820 billion kWh per year. Given the power density of the wind farm at the level of 10 MW/km^2 and the presence of significant free spaces, it is possible to assume the possibility of installing several thousand MW of wind farm capacity in Kazakhstan.

Research object: wind generators for autonomous power supply systems.

Subject of the study: modern structures for building a wind generator.

Purpose: show the most efficient wind generator systems. Analyze the role place and features of functioning of wind power plants.

Objective: factors for improving the reliability of wind power plants in smart grids.

Research methods and results: analysis, description, observation.

Various types of wind turbine-generator categories have predominated the power system application in the last decade. These types are classified and explained in [1] and [2].

There are different winds turbines generator are currently in use, classified according to the combinations between their parts and the output power converted [3, 4].

Type 1: Fixed Speed Wind Turbine Concept

Figure 1 shows a fixed speed induction generator used in WECS without power converter interface. In this configuration a starting device and step up transformer are used to connect the generator to the grid [5–6]. This is a primary and oldest technology that developed the wind turbines system. In highly converted power of WECS, the simple types of SCIG consists of 4 or 6 poles in order to operate with the rated frequencies of 50 Hz.

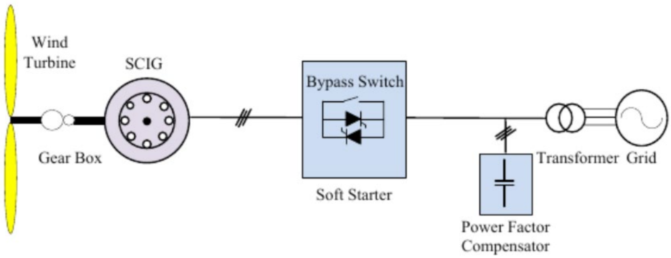

Figure 1 – Type 3 grid-connected Fixed speed SCIG WECS

The variation in rotational speed of generator is limited and approximately within 1 % of rated speed at different values of wind speeds. Therefore this type of WECS is called fixed-speed [2]. Practically, a gearbox can be used for matching the speed error between the turbine and generator. The starter device can be bypassed after starting by a switch, where the system basically works without need to the converter device.

This type of generator configuration draws a valuable amount of reactive power by the grid. To recover this situation, three-phase banks of capacitors operate as a compensator device are usually applied. The features of this configuration is simple, reliable operation and low initial costs while the main drawbacks can be addressed as: (I) lower efficiency in energy conversion; (II) the variations of the wind speed will be transferred to the grid side; and finally (III) any faults in grid side will cause huge tension on the mechanical parts of the wind turbine. This configuration of WECS is operated with auxiliary devices, like Static Compensator (STATCOM), in order to improve the operation performance and finally converge the grid code requirements [1, 5–6].

Type 2: Variable speed wind turbine with variable rotor resistance

Applying the variable speed of wind turbine generator configuration will lead to increase the efficiency of conversion process, and decrease mechanical tension which may be effected by the wind gusts, and finally decrease the bearings friction and the maintenance requirements, which finally increases the life the system at all. The wind energy system of semi-variable speed are using wound rotor type of IG and partial 10 % of rated power conversion is shown in Figure 1. The configuration of this type uses the principle of variation of the rotor resistance which affects the characteristic of torque and speed of the generator and acquiring the operation of variable speed wind turbine. The rotor resistance can be adjusted by a power converter which consists the combination of diode-rectifier and chopper circuit. This configuration is usually called Opti-slip control [4]. The range of speed adjustment is limited to be within ±10 % of its nominal speed. The operation under variable speed will enable to capture wind energy efficiently, though the existence of power losses in the generator resistance.

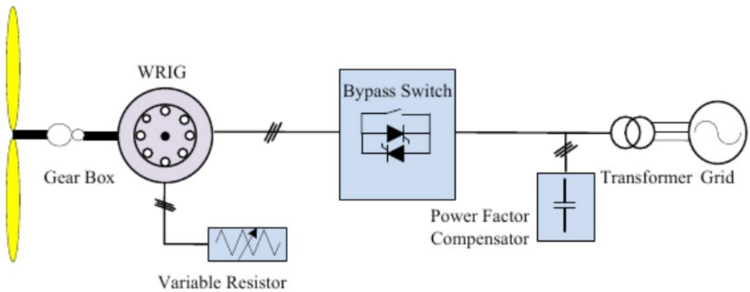

Figure 2 – Type 2 grid-connected semi-variable speed WRIG WECS

In this type, it is necessary to use soft starter, gearbox, and compensation devices of reactive power.

Type 3: Doubly-Fed Induction Generator Wind Turbine

This limited-variable speed configuration WECS applying DFIG is shown in Figure 3. The principle and operation of this type implies that the generated power is supplied to the grid by two windings, stator and rotor. A part of the converter rated power can be utilized in rotor circuit to recover the slip power, which is around 30 % of the generator rated value [5–6].

Similar to those in Types 1 and 2 wind turbines, the gearbox is also used in Type 3 configuration to obtain the required rotation speed of the rotor. At the same time, there is no need to existence the reactive power compensation devices and a soft starter in this type [5].

The power converters are used to allow bidirectional power penetration in the rotor part and increases the range generator speed.

The overall power conversion efficiency can be improved via these features to perform Maximum Power Point Tracking (MPPT) [5, 6], and increase in the speed around 30 %, may enhance the dynamic performance and strengthen the robustness against the system disturbances which are not available the Types 1 and 2 turbines [5–6]. These features enabled this type of induction machine to be one of the dominating technologies in modern electric market sharing approximately 50 % [6]. The capability to FRT is limited because the partial transfer of power. Existing of the gearbox will increase the weight of the system and overall turbine cost as well as demanding continuous maintenance.

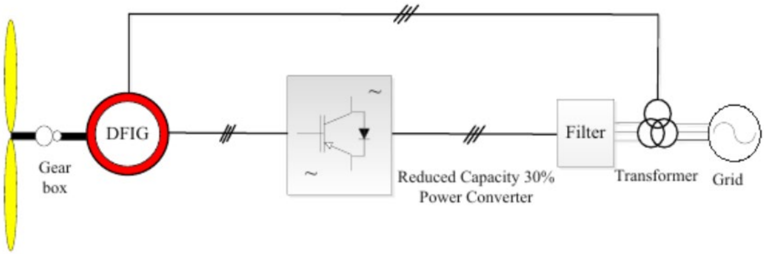

Figure 3 – Type 3 grid-connected semi-variable speed DFIG WECS

Moreover, the brushes and slip rings are needed to connect the power converter to the rotor windings through them. Regular maintenance is fundamental in these types of turbines due to ageing of brushes approximately is 6–12 months, that should be replaced periodically.

These main drawbacks restricted these types of turbines being used in offshore wind farms due to highly expensive maintenance cost.

Type 4: Variable Speed Wind Turbine with Full-Scale Converter

Using of full-scale 100 % power converters will greatly enhance the performance of WECS as shown in Figure 4. The types of SCIG, WRSG and PMSG can be applied in this configuration with a wide range of power rating reach to 8 megawatts. Since the rating of the power converters should be the same as generator rating, therefore the cost, complexity of system configuration and then the size will be increased. For this reason the losses of power converters are higher causing reduction in the efficiency of this type [5–6].

However, in this type of full power conversion, the generator and converters are fully separated from the grid, and generate full rated power during the operation at wide range of rotor speed 0 to 100 %. The power converters is also needed to compensate the reactive power and obtain smooth active power [4]. The efficiency of WECS is higher in these turbines than other types [5–6]. The best FRT compliance also can be improved and obtained without external equipment. Although the power converter cost is slightly high, it will be a small fraction; within 7 %–12 %; of overall equipment cost. By using high number of pole pairs for all types of PMSG, the turbine gearbox can be deleted [3–4].

This type of WECS is more strong against power system disturbances in comparison with the types 1, 2, and 3 wind systems.

The principle of distributed drive train is applied in developed large scale Type 4 wind system. Although WRSG and SCIG can be applied in this principle, the PMSG showed good operational performance because it removes the slip rings and brushes which provides simple design [2]. The gearbox is capable to drive multiple generators at higher speeds, therefore high power density can be obtained by the distributed drive-train and multiple generators.

Some configuration also shows effective fault tolerant in various operational conditions.

The other three converters can still deliver the power to the grid in case of failure of one converter [2]. Applying a multi-winding transformer on the grid-side leads to minimize the circulating currents and reduction in harmonics. Complicated drive-train regarded as the main disadvantage with this configuration, for this reason the designers use multi poles generator to keep the angular frequency within the rated value and eliminate the drive train.

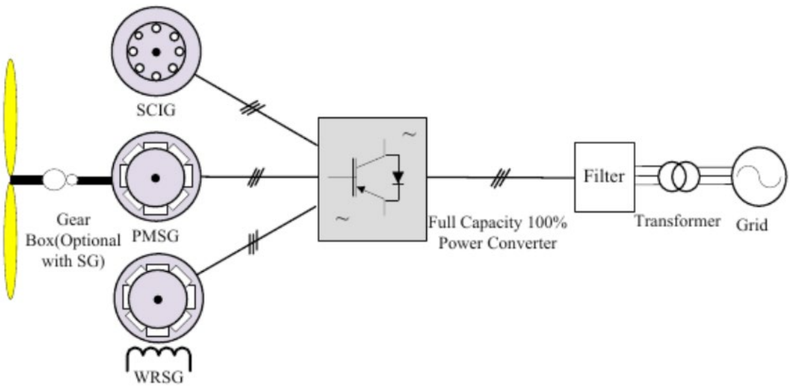

Figure 4 – Type 4 grid-connected variable speed WECS

Comparison between WECS types

The Type 3 turbines (DFIG) have been used by seven manufacturers among the top ten companies because it hold the highest market share. Approximately

100 various types of DFIG turbine models are utilized and manufactured by all the wind turbine companies.

Few of these companies produce Type 4 turbines, however very little of them are dealing with direct drive solutions. It is shown by review that the best selling and utilization of wind turbines in the electric power markets use Types 3 and 4 technologies. It is expected during coming few years that Type 4 configuration would dominate the electric power market and will have main priority in the future projects which will be held by the manufacturing companies. A brief description of all types of turbines and their manufacturing companies have been explained in detail in [7–8].

The comparison have been made depends upon electrical issues such as generator; power converters; capacity of power converter; and external reactive power compensation; compliance with the fault ride-through requirement; requirement for soft-starter, and mechanical and control issues such as gearbox and MPPT ability; aerodynamic power control, speed variety achievable; technology situation; and market penetration.

Generally, the Types 3 and 4 turbines are most suitable for large scale power grid connection and their utilizations.

Conclusions

A fixed speed induction generator used in WECS without power converter interface draws a valuable amount of reactive power by the grid. The features of this configuration is simple, reliable operation.

Applying the variable speed of wind turbine generator configuration will lead to increase the efficiency of conversion process, and decrease mechanical tension which may be effected by the wind gusts, and finally decrease the bearings friction and the maintenance requirements, which finally increases the life the system at all.

Doubly-Fed Induction Generator Wind Turbine. The overall power conversion efficiency can be improved via these features to perform Maximum Power Point Tracking (MPPT), and increase in the speed around 30%, may enhance the dynamic performance and strengthen the robustness against the system disturbances which are not available the Types 1 and 2 turbines. Existing of the gearbox will increase the weight of the system and overall turbine cost as well as demanding continuous maintenance.

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References

1 Жел-күн электрлік станциялар : Монография / С. Б. Сейтказин, А. Б. Кайдар, М. Б. Кайдар, Б. К. Шапкенов, М. С. Бектурсунова, − Павлодар : Кереку, 2019. – 175 б. – ISBN 978-601-238-894-4.

2 **Шапкенов, Б. К., Марковский, В. П., Кислов, А. П., Кайдар, М. Б., Кайдар, А. Б., Нефтисов, А. В., Волгин, М. Е., Бейсембаев, Б. У.** Топология силовой части многоуровневых преобразователей электрической энергии для автономных электроэнергетических систем / «XIX Сәтбаев оқулары» жас ғалымдар, магистранттар, студенттер мен мектеп оқушыларының : халықар. ғыл. конф. мат-дары Академик Қ. И. Сәтбаевтың 120 жылдығына арналған. – Павлодар : С. Торайғыров атындағы ПМУ, 2019. – ISBN 978-601-238-907-4 Т. 12 «Студенттер». – 2019. – 296 б. Б. 155–162. – ISBN 978-601-238-919-7.

3 **Кислов, А. П., Шапкенов, Б. К., Марковский, В. П., Кайдар, М. Б., Кайдар, А. Б., Жумадирова, А. К., Бейсембаев, Б. У.** Анализ требований, предъявляемых к системам автономного электропитания с учетом обеспечения электромагнитной совместимости / «XIX Сәтбаев оқулары» жас ғалымдар, магистранттар, студенттер мен мектеп оқушыларының : халықар. ғыл. конф. мат-дары Академик Қ. И. Сәтбаевтың 120 жылдығына арналған. – Павлодар : С. Торайғыров атындағы ПМУ, 2019. – ISBN 978-601-238-907-4 Т. 21 «Жас ғалымдар». – 2019. – 420 б. – ISBN 978-601-238-930-2.

4 Необходимость применения аккумуляторных накопителей в электроснабжении на основе возобновляемых источников / Кислов, А. П., Кайдар, А. Б., Марковский, В. П., Шапкенов, Б. К. // ПМУ хабаршысы=Вестник ПГУ. Сер. Энергетическая. – 2014. – № 2. – С. 112–117.

5 **Кайдар, А. Б., Шапкенов, Б. К., Кислов, А. П., Марковский, В. П., Жумадирова, А. К., Шахман, Е. Т.** Энергоэффективные ветрогенераторы с улучшенными энергетическими показателями / Сборник Международной научно-практической конференции «VII Торайгыровские чтения. Качество жизни в Павлодарской области. Состояние и перспективы», посвященной 55-летию Павлодарского государственного университета имени С. Торайгырова. – Павлодар, 2015. Т. 5. – С. 293–298. – ISBN 978-601-238-552-6.

6 Экспериментальные исследования инвертора с широтно-импульсной модуляцией для систем электроснабжения в возобновляемыми источниками энергии / Кайдар, А. Б., Копырин, В. С., Шапкенов, Б. К., Марковский, В. П. // ПМУ хабаршысы=Вестник ПГУ. Сер. Энергетическая. – 2014. – № 3. – С. 137–143.

7 Оценка средних и действующих значений тока, мощности статических потерь на этапах коммутации инвертора с широтно-импульсной модуляцией для систем электроснабжения с возобновляемыми источниками энергии / А. Б. Кайдар, Б. К. Шапкенов, В. П. Марковский // ПМУ хабаршысы=Вестник ПГУ. Сер. Энергетическая. – 2014. – № 3. – С. 129–137.

8 Turbulent wind component using Kaimal s function = Турбулентная составляющая ветра с функцией Kaimal / Sarsikeyev, Y. Zh., Kaidar, A. B., Lukutin, B. V., Obukhov, S. G., Kislov, A. P., Markovsky, V. P., Shapkenov, B. K., Akayev, A. M., Y. Zh. Sarsikeyev // ПМУ хабаршысы=Вестник ПГУ. Сер. Энергетическая. – 2014. – № 4. – Р. 120–125.

References

1 Zhel-kүn elektrlik stanciyalar : Monografiya. [Wind and solar power stations] In S. B. Sejtkazin, A. B. Kajdar, M. B. Kajdar, B. K. Shapkenov, M. S. Bektursunova. (eds.) Pavlodar : Kereku, 2019. – 175 p. ISBN 978-601-238-894-4.

2 **Shapkenov, B. K., Markovskij, V. P., Kislov, A. P., Kajdar, M. B., Kajdar, A. B., Neftisov, A. V., Volgin, M. E., Bejsembaev, B. U.** Topologiya silovoj chasti mnogourovnevyh preobrazovatelej elektricheskoj energii dlya avtonomnyh elektroenergeticheskih sistem [Topology of power parts of multi-branch electric power converters for Autonomous electric power systems].

3 **Kislov, A. P., Shapkenov, B. K., Markovskij, V. P., Kajdar, M. B., Kajdar, A. B., Zhumadirova, A. K., Bejsembaev, B. U.** Analiz trebovanij, pred'yavlyaemyh k sistemam avtonomnogo elektropitaniya s uchetom obespecheniya elektromagnitnoj sovmestimosti, [Analysis of requirements for Autonomous power supply systems, taking into account electromagnetic compatibility].

4 Neobhodimost' primeneniya akkumulyatornyh nakopitelej v elektrosnabzhenii na osnove vozobnovlyaemyh istochnikov [The need to use battery storage devices in power supply based on renewable sources]. Kislov, A. P., Kajdar, A. B., Markovskij, V. P., Shapkenov, B. K. (eds.). In PMU habarshysy=Vestnik PGU. Ser. Energeticheskaya. – 2014. – № 2. – P. 112–117.

5 **Kajdar, A. B., Shapkenov, B. K., Kislov, A. P., Markovskij, V. P., Zhumadirova, A. K., Shahman, E. T.** Energoeffektivnye vetrogeneratory s uluchshennymi energeticheskimi pokazatelyami [Energy-efficient wind generators

with improved energy performance. Collection of the International scientific and practical conference «VII Toraighyrov readings. Quality of life in Pavlodar region. State and prospects», dedicated to the 55th anniversary of S. Toraighyrov Pavlodar state University]. – Pavlodar, 2015. T. 5. – P. 293–298. – ISBN 978-601-238-552-6.

6 **Kajdar, A. B., Kopyrin, V. S., Shapkenov, B. K., Markovskij, V. P.** Eksperimental'nye issledovaniya invertora s shirotno-impul'snoj modulyaciej dlya sistem elektrosnabzheniya v vozobnovlyaemymi istochnikami energii [Experimental studies of an inverter with pulse-width modulation for power supply systems in renewable energy sources]. In PMU habarshysy=Vestnik PGU. Ser. Energeticheskaya. – 2014. – № 3. – P. 137–143.

7 **Kajdar, A. B., Shapkenov, B. K., Markovskij, V. P.** Ocenka srednih i dejstvuyushchih znachenij toka, moshchnosti staticheskih poter' na etapah kommutacii invertora s shirotno-impul'snoj modulyaciej dlya sistem elektrosnabzheniya s vozobnovlyaemymi istochnikami energii [Estimation of average and effective values of current, power of static losses at the switching stages of an inverter with pulse-width modulation for power supply systems with renewable energy sources]. In PMU khabarshysy=Vestnik PGU. Ser. Energeticheskaya. – 2014. – No. 3. – Pp. 129–137.

8 Turbulentnaya sostavlyayushchaya vetra s funkciej Kaimal Turbulent wind component using Kaimal s function. In [Sarsikeyev, Y. Zh., Kaidar, A. B., Lukutin, B. V., Obukhov, S. G., Kislov, A. P., Markovsky, V. P., Shapkenov, B. K., Akayev, A. M., In PMU habarshysy=Vestnik PGU. Ser. Energeticheskaya. [PSU Herald. Series Energetics]. – 2014. – № 4. – P. 120–125.

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С. К. Шерьязов[1], С. С. Исенов[2], А. Б. Кайдар[3]

Классификация систем преобразования энергии ветра

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Мақалада жел энергетикалық қондырғыларының рөлі, орны және жұмыс істеу ерекшеліктері талданады. Генераторлардың әртүрлі нұсқалары және жел энергиясын электр энергиясына түрлендіру схемалары келтірілген. Қолданыстағы жел агрегаттарына егжей-тегжейлі талдау келтірілген. Зияткерлік желілердегі Жел энергетикалық қондырғылар жұмысының сенімділігін арттыру бойынша ұсыныстар берілді.

Кілтті сөздер: жел электр станциялары, жел турбиналары, белгіленген айналу жылдамдығы бар жел турбиналары, жел турбинасының асинхронды генераторы, қос қуатты, ауыспалы.

В статье проведен анализ роли, места и особенностей функционирования ветроэнергетических установок. Даны различные варианты генераторов и схемы преобразования энергии ветра в электрическую энергию. Приведен детальный анализ существующих ветровых агрегатов. Даны рекомендации по повышению надежности работы ветроэнергетических установок в интеллектуальных сетях.

Ключевые слова: ветроэлектростанции, ветротурбины, ветротурбины с фиксированной скоростью вращения, асинхронный генератор ветротурбины, с двойным питанием, переменная.

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