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Overview of SMES Units Application on Smart Grid Systems A. M. Shiddiq Yunus and Makmur Saini Energy Conversion Study Program, Mechanical Engineering Department Politeknik Negeri Ujung Pandang (State Polytechnic of Ujung Pandang) Makassar, Indonesia shiddiq@poliupg.ac.id

Abstract—Many papers have introduced the wide application of SMES Unit in Power Systems.

Since introduced at the first time in 1911 by Dutch Physicist Heike Kamerlingh, Superconducting magnetic technology has attracted many researchers to investigate its application in many areas. It was reported that its first application study in power systems was in transmission line stabilization in 1987. Since that the study of SMES application in power systems become even wider not limited only in system stabilization during faults but also in smoothing out power output from renewable energy based power systems.

Moreover, the booming trend of smart grid with its complexity has attracted SMES researchsers to involve the SMES in improving the reliability of smart grid systems.
Keywords— Power; SMES; Smart Grid and Wind Introduction Since introduced first in 1911 by Dutch Physicist, Heike Kamerlingh [1], superconductor has attracted scientists to intensify their research on very wide applications.

There are a lot of designs and models of using superconductor in some areas of interest, for example; application on levitated trains by using very strong superconductor magnet [2], bio-magnetism to deliver drug in human body [3], electric generator where its wire is made from superconductors material [4,5], antenna system [6], augmented rail gun system [7], analog to digital converters application [8] and application in thin film for microwave applications [9].

The International Superconductivity Industry Summit (ISIS) has released a projection of superconductor up to 2020 as can be seen in Fig.1. In power system, SMES Units studies and projects were applied on conventional power systems and used to improve the system stability on SSR phenomena as discussed in [10]- [12].

Since the issue of environmental problems due to exhausted CO2 from conventional based power systems, the electric power industries moved to renewable energy sources to mitigate the negative impacts of the conventional power plants. There are two popular renewable energy sources used in the last decades, wind and solar energy. As reported in Global Wind Energy Council [13], number of wind turbine generators installed worldwide until 2014 has achieved about 369,553 MW.

Meanwhile, PV installed worldwide is about 139,000 MW in 2014 [14]. / Figure 1. ISIS projection on Superconductor’s industrial share market [1] Since the rapid fluctuation of wind speed from time to time, it is necessary to design the wind turbine system to be adaptable with the rapid change of wind speed, therefore, there are many papers proposed technical system to achieve this function, where optimal design in blades control systems are introduced [15]-[17].

Besides control scheme were focused on blade mechanism control of the wind turbine system, some wind turbine manufactures such as Siemens, GE, and ABB Ltd, with 1.5-2.85 MW turbine generators, also developed control of power electronic systems of the turbine along with the mechanical control [18]. For example the use of Doubly Fed Induction Generator (DFIG) where power electronics are very reliable to smooth out the power output even in the condition of rapid wind speed fluctuation [19]. Figure 2 shows the typical system of DFIG. _ Figure 2.

Typical configuration of WTG equipped with DFIG [20] Application of energy storage systems to assist the wind turbine generators were also introduced in some papers, particularly on fixed speed-direct connection wind turbine generators, in smoothing out the output power of the wind turbine generators. The storage energy systems could battery [21], SMES Unit [22]-[25] and combination of them [26, 27].

In [22], SMES Unit is applied to maintain the initial state of DFIG performance during fault at the grid. The overall system including the converter systems is shown in Fig. 3. In conjunction with [22], new application of SMES Unit to maintain the DFIG operation during internal faults of misfire and fire-through in the DFIG's converter is studied in [23]. / Figure 3.

DFIG System equipped with SMES Unit [23] SMES Unit Basic Operation SMES Unit basically works based on natural uniqueness of inductor in storing energy as can be stated in the form of equation below: ??= 1 2 × ?? ×?? 2 (J) (1) Where E is stored energy (Joule), L is inductor (Henry), and I is current flow in Inductor (A). When a conductor is placed in a very extreme low temperature or aforementioned as cryogenic temperature (about -269oC), the conductor will have properties of superconductor state, where the value of resistance will extremely drop to almost zero.

With very low resistance, a superconductor will have a very high efficiency due to the current that is flowed in the conductor encounter almost no resistance. Fig. 4 shows the diagram of a SMES Unit. / Figure 4. Schematic diagram of a SMES unit. [23] Figure 3 shows the typical schematic of DFIG that is equipped with a SMES Unit.

A SMES Unit typically consists of a superconducting coil, a cryogenic refrigerator, a power conditioning system (including converters and control system), and a cryostat/vacuum vessel to maintain the coil at a very low temperature that is required to keep the SMES coil in the superconducting state. The efficiency of this configuration is very high in the range of 95%–98% [28]–[30].

Moreover, a SMES Unit could charge and discharge its energy in very rapid response and smoothly decoupled active and reactive power modulation in four-quadrant operation that makes it appropriate for high power applications. [31]. Environmental issues associated with the formation of strong magnetic field and its high implementation cost becomes the main disadvantages of a SMES Unit [32].

However, with the latest improvement of high-temperature superconducting (HTS) materials and the concept of undergrounding the installation of the whole unit, the applicability of SMES Units on power systems are expected to become much more popular and practically implemented in the near future [33]. Application on Smart Grid Systems Smart Grids terms become very famous recently in power engineering because it concerns more about massive involving of renewable energy based power plants, smart storage energy system, smart compensators devices involvement, large electric vehicle charging and discharging process, and not less important the ICTs (information and communication technologies) support to comply all these integrated components with the existing grids.

The smart grid concept even much become more complex with the possibility of personal electric vehicle and individual residential PV home to supply the grid when have excessive power production [34]. The smart generator sizing for electrical power transmission line is also become important part for smart grid concept [35]. The example description of smart grid system from AEG Power Solution is shown in Fig.4 [36]. / Figure 4.

Smart Grids Concept from AEG Power Solution [36] The complexity of smart grids become more challenging, where smart grid not only covers smart energy management but also the reliability of the smart grid systems that involves distributed renewable energies and V2G (Vehicle to grid) or G2V (Grid to vehicle) scheme. Therefore, some papers have been published in regards of SMES application to support the reliability of smart grid systems.

The selection of SMES Unit in smart grid studies of course, is based on the aforementioned benefits of SMES unit including fast charge and discharge rates, high capacity of power store and could also provide limited reactive power (four quadrant operations). In [36], there are four specification of SMES Units are proposed where these four SMES Units divided into two type coils; Solenoid and Toroid.

Moreover, the four concepts of future energy storage systems for smart grid are compared based on their capacity, efficiency, control and capital cost. The four storage energy concepts are sole SMES, SMES-based HESS (Hybrid Energy Storage System), DSMES (Distributed SMES) and SMES-based DHESS. The concepts of SMES application in future smart grid is shown in Fig. 5.

/ Figure 5 Prospect Concept of SMES devices application in a future smart grid [36] The promising research progress of HTS (High Temperature Superconductor) materials and HTS SMES applications, the combination between hybrid ESSs (Energy Storage Systems) and DSMES schemes becomes more promising prospects in future smart grids, not limited only on power generation side but also prospective on power transmission, power distribution and power consumer side.

Moreover, capital cost for SMES devices could significantly reduced with the low price of BSCCO tapes based-HTS and YBCO tapes based-HTS conductors, SMES device with larger scale will become economically available and be an important part of future smart grids [37]. Application of SMES in micro-smart grid applied with ICTs is discussed in [38].

The concept of micro smart grid with wind farm, PV station and roof top PVs and public EV charging station involvement causing very complex energy management, therefore an energy storage system is required to meet the energy demand and to stabilize the whole system. The concept of micro grid with energy storage is depicted in Fig. 6. Various energy storage systems that are offered in [38] are SMES, Supercapacitor and Flywheel. / Figure 6.

General concept of a smart micro-grid with ICT's architecture [38] In [39], A novel study of transient stability of a smart grid system that is involving SMES and Gridable Vehicles (GVs). SMES and GVs in this paper are used to stabilize the system under study (Fig. 7) when 1-LG and 3-LG faults are occurred. The study come up with conclusion that contribution of GVs is lesser compared to SMES in stabilize the system under study during faults. / Figure 7.

Proposed System under study with SMES and GVs [39] Conclusion The smart grid concept initially will take renewable energy based power plants such as wind and PV as inseparable part. Moreover, rapid plugging of electric vehicle also involved in smart grid system. The challenge become more complex with the concept of smart metering that allows for personal/individual owner of PVs and EVs to sell their excessive power production to the grid.

Therefore, SMES in this concept become an option to fulfill the energy demand and to stabilize the grid during faults and during very large intermittent from wind and PVs.

Some overviewed papers proposed a study of application of SMES in improving the reliability of smart grids in the future. Acknowledgment Authors would like to thanks Center of Sustainable Energy and Smart Grid Applications (COSESGA) and Director of Politeknik Negeri Ujung Pandang for supporting and sponsorship the study and to attend the conference. References www.superconductors.org W. Jiasu, W. Suyu, and Z.

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