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Low voltage system design for buildings

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ABSTRACT

In this study, a low voltage distribution system is proposed for buildings with distributed generation and electrical buildings. The projected low voltage distribution system includes both AC distribution system and direct DC distribution system for the energy requirement of the loads. With the installation of DC distribution system, the restriction for distributed generation and consumer devices to be compatible with AC low voltage distribution system is eliminated. DC and AC distribution systems are interconnected through a rectifier for the supply of DC load increases from AC mains and for unidirectional power flow. Low voltage distribution system is installed along with the distribution management system that utilizes grid technologies by also considering the electricity prices in deregulated market for increasing the power quality and energy efficiency of AC/DC low voltage distribution system. Power quality monitoring system, control of distributed generation, charging of electrical vehicle, and similar subsystems are used in conjunction with distribution management system. By using the daily load duration curves for summer and winter seasons of the low voltage feeder supplying buildings that also takes into account the effects and energy unit prices of electrical buildings charging systems and photovoltaic systems is introduced in this study.

Keywords: Low voltage, DC Distribution, Electrical Buildings, Distributed Generation.

1.0 INTRODUCTION

The increase in the per capita consumption of energy along with the world population raises the energy requirement more with each passing day. That the energy requirement increases on one. hand and that the lifecycle of fossil fuels is restricted and that the gases arising by burning these fuels rise the global warming on the other hand bring the studies carried out with respect to energy into prominence. In 2008, the EU decided to reduce greenhouse gas at least by 20% in 2020 compared to 1990, to supply 20% of energy needs by 2020 from renewable energy sources (RES) and to reduce 9% energy usage by the 2016 compared to 2005 levels. [1-3]. The increasing energy requirement and the adverse effect of fossil fuels on environment made the use of RES a current issue. However, that the RES are generally small power is one of their important disadvantages. Furthermore, it is necessary to overcome significant difficulties in the integration of such sources with the available AC electric network owing to the fact that most of the RES generate DC power [4]. The increasing energy requirement has brought the more efficient use of available energy into prominence as well as new resource seeking. In recent years, it has been given importance that the newly designed devices use the energy efficiently [3]. However, it is not considered sufficient for energy saving that the new devices are designed to consume less energy. In addition to this, it is still carried on seeking for reducing energy losses occurred during the course of transmitting the energy consumed by the devices to the devices through the power plants. Distributed Generation (DG) are close to the end user helps in reducing the transmission, distribution and transformation losses of energy is one of the significant advantages of such sources.

In recent years, the demands for high power quality are increasing day by day due to the devices sensitive to power disturbances as well as the increasing energy demands of electricity consumers [5]. Power quality problems can cause processes and equipment to malfunction or shut down[6]. During the past decade, there have been several efforts to assess the cost of poor power quality for individual consumers and companies [7]. In houses and offices, the use of electronic devices consuming DC energy is rapidly increasing [8]. In addition to this, significant amount of DC energy will be required for electrical buildings (EV) to be charged within the next years [9]. The recent developments indicate that a considerable part of the energy used in the buildings will be consumed as DC. That many RES available at end users side generate DC energy reveals the insufficiency of the available AC network infrastructure. The requirement for a new network that is more advanced than today's network infrastructure is revealed for the available electric energy systems both to include DG and to meet the demand for high power quality and energy efficiency. A Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies [10].Grid aims to achieve flexible, accessible, reliable and economic future electricity networks [11]. The subject of DC distribution system, which has significant advantages for electric energy to be used efficiently in houses and commercial buildings, for the high power quality demands of devices to be met and for the DG to be integrated to the network more easily, has been an essential field on which the researchers make their studies concentrate in recent years [12]. This study is related to the SLVDS which meets the energy requirement of DC and AC loads available in the buildings, which will facilitate the connection of DG to the network, which will improve the energy efficiency in the building by reducing the transformation losses, which will meet the high power quality demand, which is designed so that it will reduce the adverse effects of harmonics of nonlinear loads on AC network and which is operated flexibly. In the final chapter, there is given a study concerning the in a low voltage distribution system (LVDS) in which DC and AC systems are used together.

2.0 PROPOSED LOW VOLTAGE DISTRIBUTIONSYSTEM

Nowadays, AC has been preferred in the generation, transmission and distribution of electric energy. The electric distribution systems feeding the buildings are also installed and operated as AC. The history showed that new houses and commercial buildings are constructed as the population increases and new ones are added to the devices used in daily life depending on technological developments as the level of welfare raises. The share of the energy amount used in houses and offices within the entire consumption is increasing with each passing day .

In recent years, a rapid increase has been seen in the number of the devices operated with direct current, such as personal computers, mobile phones, sound and video devices, lighting with LED and so on. In addition to all of these devices, AC/DC transformation is required for charging the EVs being a significant electrical load of buildings. A considerable part of electric energy is lost through energy transformations. Moreover, the efficiency of these harmonic currents of rectifier decreases by causing additional losses in AC system .

When the high quality energy requirement of loads is considered, the energy storage is brought into prominence promptly and electric energy is stored as DC . The UPS systems are used for such devices that are sensitive against power disturbances. The UPS systems used have adverse effect on the energy efficiency due to their losses.

Within the last ten years, the electric power sector has been in a state of significant change and the restructuring studies for ensuring more liberality and freedom in the operation of the electricity market have accelerated. The electric distribution network has gone through a structural change along with the liberalization in the energy market in parallel with the increase in the use of DG .

Notwithstanding the considerable increases in the number of DG, it cannot be expanded sufficiently due to the crucial difficulties encountered in connecting most of the small power generation plants generating DC energy to AC distribution network. A considerable part of DG generate DC energy and are connected to AC system through DC/AC transformers .

A variety of reliability indices for distribution systems have been defined by IEEE Working Group on System Design . System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) are considerably high in developing countries [29]It is possible to reduce the adverse effect of interruptions on consumers by means of small power generation plants. In addition to this, the use of various energy storage opportunities along with the DG will improve the reliability .

Upon the inclusion of LED lighting and EV charging systems to the prevalence of DC energy use in consumer devices in recent years, the ratio of DC energy use in houses and commercial buildings has been considerably increased. However, the requirement for DC energy is still supplied from rectifier AC/DC transformers due to the existing LVDS.

The idea of bringing the devices consuming DC energy in buildings (EV charging, LED lighting, Computer and electronic devices, etc.), the devices storing the energy as DC (Flywheel, Ultra capacitors and Battery) and generating DC energy (Small wind turbines, Micro turbines, Fuel cells, PV) and DC refrigerator and DC Freezer which are still operated by AC voltage, but which can be designed subsequently so as to be operated by DC voltage together in a common DC bus as shown in the Figure.1 grows stronger day by day.

The requirement for DC low voltage distribution system will be increased more because of the increase in DC energy use ratios in buildings upon designing such devices as lighting technologies, cooking and heating systems, which do not have to be operated by AC, but which are designed so as to be operated by AC voltage due to the reason that the electricity is distributed by AC voltage, so that they will be operated by DC voltage. In literature, the techno-economic analysis of DC distribution system presented the difference between AC and DC .

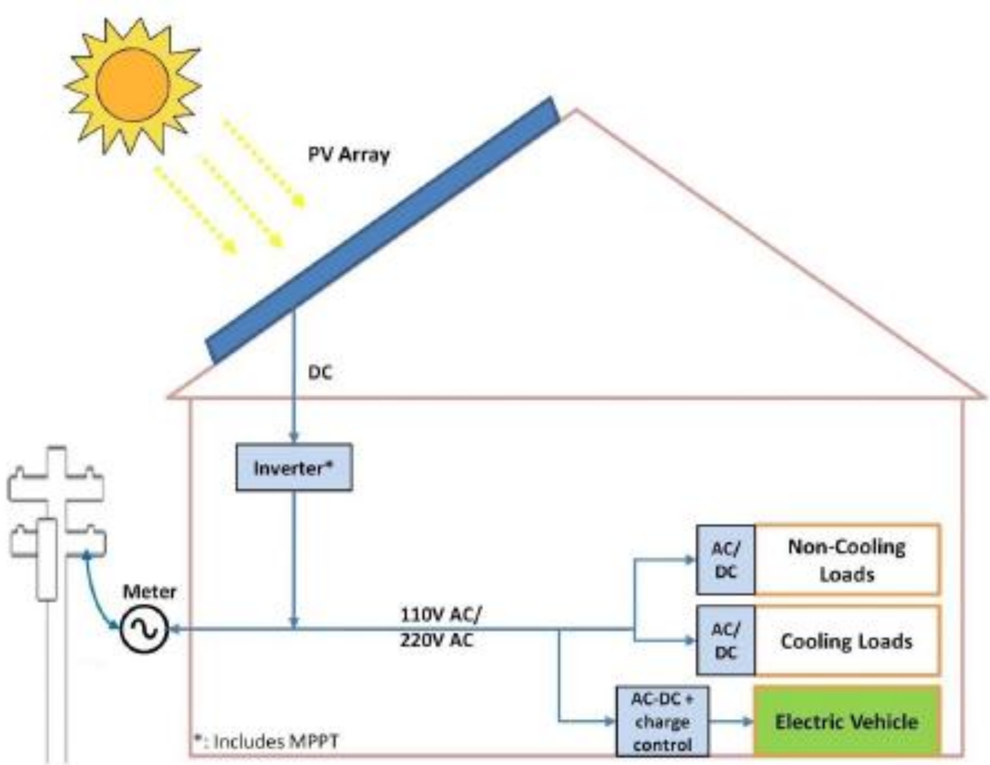

Figure.1: DC bus for building

The advantages of using DC LVDS in supplying power to buildings can be summarized as follows.

- That the integration of small power DG to DC system is easier than the integration to AC system will contribute to the expansion of DG.
- Since the DG and DC energy storage capacity will meet the emergency requirement against network disconnections for a certain period, there will be reliability increase.
- Charging of EV and resupply of the building from electrical buildings (V2G) become

simpler.

- As the problems regarding AC voltage inferiority will be considerably reduced by DC voltage, the problem of breakdown or malfunction of sensitive electronic devices fed by DC voltage due to energy inferiority will be reduced.
- With the supply of DC devices from DC system and the decrease in the number of rectifier, the voltage inferiority and additional losses caused by harmonic currents run by DC devices to AC system will be reduced.
- The number of AC/DC and DC/AC converters will decrease. The decrease in the number of converters will reduce the operating costs by reducing losses while it reduces the installation costs.

The most crucial problem in DC distribution system, however, is that DC voltage values of devices are very different from each other and that there is no standardization with regard to DC voltage as in AC system. There are so many different voltages used in feeding DC devices due to the lack of standard. This leads to the increase of the requirement for the number of DC/DC converters. The decrease of both the number of DC/DC converters and their costs is one of the challenges required to be overcome for the transition to DC distribution system.

In addition, even though it is possible for many devices that are still operated by AC voltage to be designed and operated by DC voltage, this conversion will lead to significant costs. As of today, it is too early for the available AC LVDS to be fully superseded DC LVDS. It will be more suitable method that the LVDS is performed through both AC and DC system from the low voltage side of distribution transformer. Furthermore, the common use of AC and DC for the low voltage distribution will gather the advantages of AC system and DC system. During the design stage of the devices, developing more liberal designs without the necessity to choose AC or DC will give chance to the occurrence of the optimum designs in terms of energy use in the long term.

DG connected to AC network causes short circuit power increase in the existing network. The increase in short circuit power reveals the necessity to renew the circuit breakers. In addition to this, in the case of energy flow to AC system by consumer, the requirement for renewing the protection systems that are designed according to unidirectional feeding arises.

Furthermore, it will be a more suitable solution to support the existing system with DC distribution instead of renewing it in order to meet the load increase in considerable amount arising from the electrical vehicle charging stations.

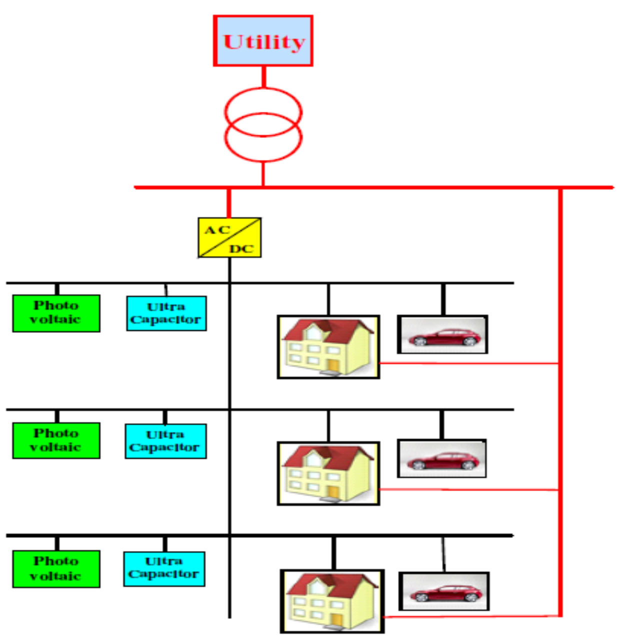

Figure : 2An Example of Proposed Low Voltage System

- The number of rectifier has been reduced between AC and DC systems.
- It has provided the opportunity for DC resources to back-up one another.
- It has allowed meeting an increase in DC loads in any building with a decrease in another building. In other words, the requirement for installed capacity of DC resource will be reduced due to synchronization.
- It allows for planning the charging of more than one electrical vehicle.
- Ensuring the voltage quality in DC distribution system will be easier than ensuring the voltage quality in DC bus of any building.
- The energy flow is made unidirectional via diodes in DC system whereas the supply of failure points by resources causes reliability problem in terms of resource and network in AC system.
- The rectifier will provide support from AC network in the event that the power generated from the RES does not meet the demands of DC loads.
- In case of power outage in AC system, AC loads will be disabled automatically due to unidirectional feeding. If there is power in the solar system with ultracapacitor, the block will carry on feeding the entire of DC loads in the building or urgent DC loads by remaining in working condition.

It is seen that the proposed LVDS is considerably complex in terms of operation when compared with the conventional distribution systems as well as their superiorities. The use of the LVDS proposed in this chapter together with the network technologies that show rapid development each passing day will eliminate the potential challenges.

3.0 LOW VOLTAGE DISTRIBUTION

In the proposed low voltage distribution system, the communication infrastructures, algorithms and technologies are required for increasing the energy quality and energy efficiency, for obtaining the tariff data of the electricity market as online, and for optimizing the energy consumption and energy generation by DG.

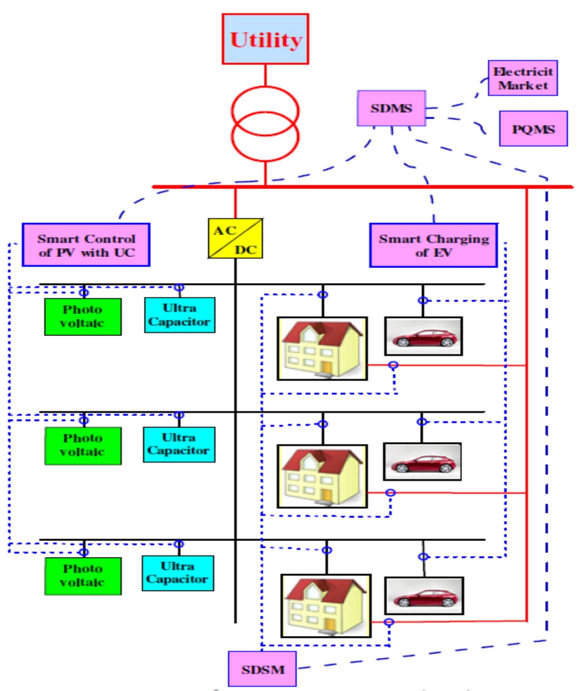

Figure.3: An example of low voltage distribution system

SDMS will form an environmentalist system that will be able to sense overloads with its real-time communication infrastructure, will regulate the energy flow directions, will optimize the use of RES and that will reduce the user costs. SDMS is based on real-time data collection. SDMS computers for rapid decisions analyze this data, most of the problems that might arise are avoided by preventive measures or it is ensured that the distribution system repairs itself by eliminating the problems arising or by isolating from the distribution system. It is possible to prevent disconnections by means of fault status and overload control.

In conventional approach, the management of distribution network and loads are comprehended as such processes that are independent from each other. With the gradually increasing number of DG, a change has begun even if it is slow. In the , the loads and DG should be evaluated together.

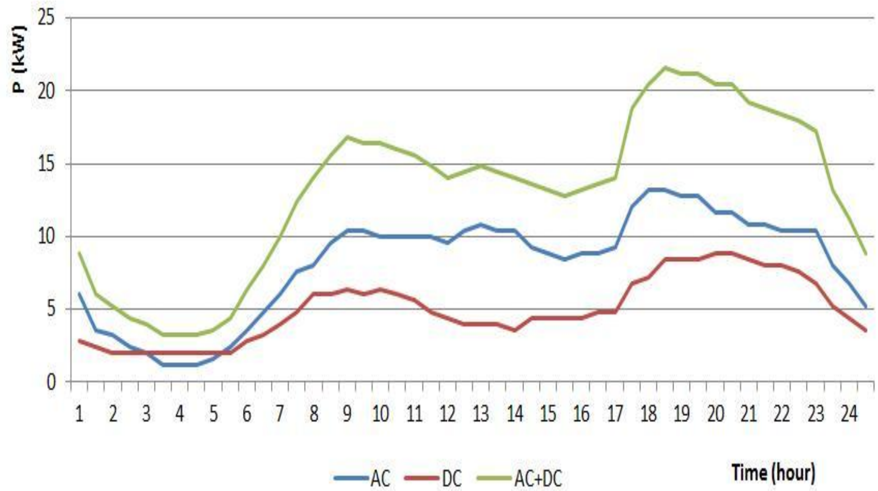

Figure.4: Load curve along a typical Winter day

EV charging units can be operated as three-phase or single-phase. Three-phase charging provides higher power and more rapid charging opportunity. However, buildings do not include three-phase system all the time. Single-phase energy can be supplied more commonly. The single-phase charging current is generally at the degree of 10 A and rapid charging current at the degree of 30 A. The single-phase and standard charging process usually takes 6 hours. By taking account of the load duration curve, slow charging is preferred by the charging system.

The multi-time tariff treatment of the distribution company from which the buildings purchase energy is between 06:00-17:00 as standard, between 17:00-22:00 as peak and between 22:00-06:00 at night. For residences, the tariff charges of 2010 for these tariff periods are 0.118, 0.188, 0.071 $/kWh in the same order []. Since there is no energy generation in PV system at night, the period between 22:00-06:00 during which energy is the cheapest in triple tariff system from the network over a rectifier for charging of the electrical buildings preferred the charging system.

The charging system determines the period between 22:00-06:00 as the most appropriate hours in terms of DC and AC network loading as well as in economic terms.

The energy generated in PV system of 50 m2 and 500 W in each house is insufficient to meet the requirements of DC devices in the buildings. If the energy generated in PV system is more than the requirement, the rectifier between AC and DC systems will prevent it.

4.0 RESULTS AND DISCUSSIONS

In this study, when DC load duration curve in the Figure is examined, the nighttime during which DC load is lower is preferred for preventing electrical buildings from overloading DC system. The influence of normal charging of EV charging on the daily load duration curve for winter season is given in the Figure and on the daily load duration curve for summer season in the Figure. It is seen that EV charging systems cause significant increases in DC load duration curve. Since there is no energy generation in PV system at night, DC energy is supplied from the network over a rectifier.

When the DC daily load duration curves for winter and summer seasons are examined in the Figure, PV system does not meet the daytime requirement for DC energy generated.

The Figure was used for the electric energy generated by PV roof systems in the buildings in summer and winter periods. The instantaneous changes in output powers of solar cells within daytime by the use of solar cells together with ultra capacitorwere not taken into consideration.

Due to the reason that PV system does not supply DC load in daytime and that no DC energy is generated at night, the requirement may be met through a fuel cell that will be able to generate energy during day and night for the requirement of DC distribution network. However, DC system and DC DG should be designed so that DC load is supplied since it is assumed that there will no energy flow from DC low voltage distribution system to the direction of AC network.

5.0 CONCLUSION

In the future, it is expected that the electrical buildings charging systems connected to the low voltage distribution system will rapidly become widespread. In the available low voltage distribution system, the requirement for upgrade will occur due to the problems of voltage collapse and overloading of network components during charging a large number of electrical buildings at the same time. The sufficient-sized DG meets the requirement for upgrade through the connection of the low voltage distribution system to the building side where the electrical vehicle charging systems are installed. The hybrid low voltage distribution system to which both AC and DC low voltage distribution systems are connected over a rectifier from the low voltage distribution transformer will be an appropriate network model for meeting the future requirements.

The advantages of using AC and DC together for low voltage distributions are summarized below.

- During the design stage of the devices, developing liberal designs without the necessity to choose AC or DC will give chance to the occurrence of the optimum designs in terms of energy use in the long term.
- The restriction that the new consumer devices and power generation always have to be AC will have been eliminated.
- Both the difficulties encountered in connecting small power DG to AC LVDS and the requirement for DC energy source required for EV charging will accelerate the expansion of DC LVDS.
- The interconnection of DC and AC systems via a rectifier prevents the energy flow from DC DG to AC network. Because of this, the requirement for making change in the protection and operation of electric distribution system designed according to unidirectional feeding will be eliminated.
- It is expected that the collocation of AC and DC distribution systems will become widespread with the development that will occur in relation to the standards.

While operating AC and DC LVDS, technologies are required as well as the standards. The advantages of co-management of AC and DC LVDS by means of technologies are summarized below.

- The interconnection of a DC LVDS and DC MicroGrids belonging to more than one building allows for the co-management of DC load demands and DC DG.
- In order to reduce the adverse effect of EV on LVDS the number of which is increasing rapidly, it will be possible to design SCEV systems that use AC load profiles, DC load profiles, online data and tariff information of the electricity market in determining charging periods, start time for charging and charging technique.

The most essential problem in DC LVDS is that DC voltage values of devices are very different from each other and that there is no standardization with regard to DC voltage as in AC system. The decrease of both number and costs of DC/DC converter is one of the difficulties required to be overcome for the transition to DC distribution system. In spite of all difficulties, it is expected, in the long term, that DC LVDS will become widespread along with AC LVDS feeding the buildings.

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