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A Empirical Research upon the Fundamental Concepts of Electrical Power Distribution

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Abstract – Many new primary energy sources in distributed generation systems are interfaced with the electric grid through power electronic inverters. If several of these are present in proximity of each other, interactions between them could arise. Thesis presents a study of the interaction between hysteresis controlled voltage source inverters connected to the same power network. The coupling between the inverters results in an interdependence of their switchings. It is shown that this interdependence is not detrimental, and a reduction of the ripple in the resulting current supplied to the network as compared to the single inverter case is obtained. The effects of various parameters of the inverters are analyzed.

A set of three scenarios has been created in order to examine the incorporation of extensive penetrations of micro-generators into electricity networks (termed 'highly distributed power systems'). The scenarios have been created as a synthesis of the Future Network Technologies scenarios and the UK domestic carbon model, and yields energy use and carbon dioxide emissions of the UK housing stock from inputs of household numbers, house type, thermal efficiency, appliance efficiency, as well as the number and efficiency of micro-generators used.

The centralized supply mix also varies between scenarios and features extensive penetrations of large-scale renewables. This paper provides an overview of electrical distribution network and systems. The primary substation is the load center taking power from the transmission or subtransmission network and distributes electricity to customers via the distribution network consisting of cables. OHL and customer substations. Various power system components, like Circuit breaker. OHL. cables, and secondary equipment like protection relay, distribution automation are presented. The distribution system from planning, design, implementation, operation and maintenance is also described. The performance features of the distribution systems in terms of a number of measurable indices are highlighted.

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INTRODUCTION

Traditionally, power generation for an electronic system was assigned a particular location in the system's structure where a central power supply would reside, powering all the system's elements through a network of cables or buses as shown in Figure 1. The advantages of this approach include concentrating all the power processing technology - including thermal management - into a single box which could then be designed, subcontracted, or purchased as a stand-alone item. This was particularly appropriate if the system designer did not own the necessary power processing expertise.

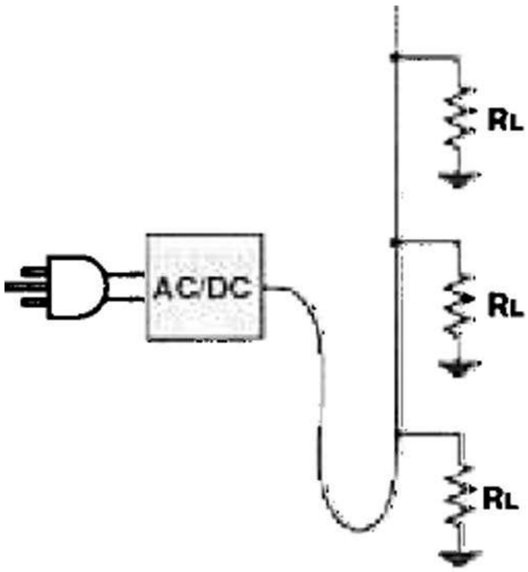

Figure 1 - Central Power

Distributed power, such as an approach shown in Figure 2, represents a converse technique. In a distributed power system the system's power requirements are allocated to a number of smaller power processing units which are then distributed throughout the system in a variety of architectures, usually with the intent of bringing power processing closer to where the power will be used. While the ultimate extension of this concept is the "on-card" regulator or power supply, many other solutions for distributing power processing tasks are common. Before discussing the various architectures, however, it is helpful to understand the motivation for considering distributed power.

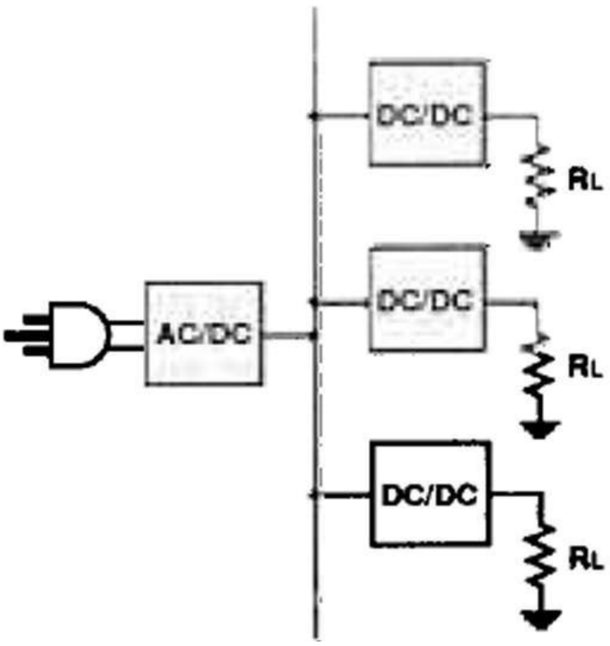

Figure 2 : Distributed Power

The primary purpose of an electricity distribution system is to meet the customer's demands for energy after receiving the bulk electrical energy from transmission or subtransmission substation. There are basically two major types of distribution substations: primary substation and customer substation. The primary substation serves as a load center and the customer substation interfaces to the low voltage (LV) network. Customer substation is referred to a distribution room normally provided by the customer. The distribution room can accommodate a number of HV switchgear panel and the transformer to enable LV connection to the customer incoming switchboard.

Depending on the geographical location, the distribution network can be in the form of overhead lines or underground cables. Cables are commonly used in urban areas and overhead lines are adopted for rural areas. Different network configurations are possible in order to meet the required supply reliability. Protection, control and monitoring equipment are provided to enable effective operation of the distribution network.

Planning of the distribution network is essential to enable the required demand can be met based on various forecast loading figures and supply security./reliability. There are three categories of planning, namely the long-term planning, the network planning and construction planning. Long-term planning is to determine the most optimum network arrangements and the associated investment with consideration on future developments.
Stage-by-stage development must be in line with the forecasted load growth so that electricity demands can be timely met. The construction planning or design is the actual design and engineering work when the required circuits and substations have been planned and adopted.

BACKGROUND

In the 20th century, the United States developed an electric power system (EPS) that became the envy of the world for its reliability and low-cost power. Today, the US electric power system consists primarily of large, central-station plants interconnected via a high-voltage transmission system that delivers power to end-users through lower-voltage, local distribution networks. However, interest in the use of distributed generation (DG) and storage has increased substantially over the past 5 years because of the potential to increase reliability and lower the cost of power through the use of on-site generation. The advent of competition in the electric power industry, through which customers can shop for the ideal solution for any situation, has been a stimulus for this increased interest. The development of small, modular generation technologies such as photovoltaics, microturbines, wind turbines, Stirling engines, and fuel cells has also contributed to this trend.

DG and storage can have many benefits. However, the technologies and operational concepts needed to properly integrate them into the power system must be further developed to achieve these benefits while avoiding negative effects on system reliability and safety. The current power distribution system was not designed to accommodate active generation and storage at the distribution level. Compatibility, reliability, power quality, system protection, and safety issues must also be addressed before the benefits of distributed power can be fully realized.

Although existing literature addresses the requirements of DR operation and interconnection to the distribution system, the cumulative effect of numerous types of DR on a given feeder is less understood. The extent of the eventual integration of DR into the electrical distribution system will depend on the limits imposed by the local grid. These, in turn, are determined by a number of utility coordination issues, including the proper performance of utility fuses, reclosers, and protective relays.

ADVANTAGES OF DISTRIBUTED POWER

While not all of the following list of potential advantages are common to all distributed power configurations, it is still a list worthy of consideration during any power system definition phase.

1. Standardized designs: A centralized power supply almost by definition must be designed specifically for each new set of requirements. A goal of distributed power is the availability of standardized off-the-shelf modules or designs which could be combined in a variety of ways to meet a specific application. This has obvious benefits in development time and engineering costs as well as the confidence gained from using pre-qualified power components.

2. Ease of customizing: If unusual requirements are encountered, it is much easier to modify, redesign, or replace a smaller power module allocated to the unique portion of the system than to redesign a larger central power supply. Customizing a supply delivering common load voltages is often as easy as paralleling the required number of standard power modules needed for a given requirement. A corollary of this benefit is the ease of accommodating system growth, or recovering from an overly optimistic initial estimate of the system's power needs.

3. Maintainability: With distributed power it is possible to localize and isolate faults much more readily and, with properly designed parallel systems, on-line replacement (hot-swapping) will allow repairs to be made with a minimum of down time.

4. Packaging: A look inside any kilowatt or larger power supply will impress anyone with the significant amount of mechanical hardware necessary for high power processing. Clearly, these requirements are greatly diminished as the power level is reduced and the need for heavy bus bars and special heat sinks is diminished. This benefit also has a corollary in thermal management where a distributed power system, by distributing the sources of heat generation, can often rely on conducted or radiated cooling, sometimes eliminating the need for air moving equipment.

5. Power density: If all else is equal, it would probably take considerably more volume to house n modules than a single power supply with n times the power, however all else need not be equal. Specifically, as the power level goes down, the switching frequency can go up without a decrease in efficiency, resulting in greatly enhanced power density for lower power modules. Ongoing improvements in the technology of almost all the components which go into a power supply are continually enhancing this benefit as distributed power modules with power densities of 50 to 100 W /in3 are becoming available.

6. Reliability: The reliability of a power system is obviously enhanced if it consists of a paralleled configuration of n+y modules where n is the minimum number of modules necessary to meet a given load requirement and y is a number of additional units (usually I) which gives the system the ability to tolerate y failures without impact. While reliability is certainly affected by the relative design philosophies used, it can usually be shown that while the number of components may go up in a distributed system, the lower power levels result in reduced stress levels, both electrical and thermal, benefiting overall reliability.

7. Efficiency: As load voltages are reduced, the IR drops in the power distribution conductors become ever more significant. A major benefit and goal of distributed power should be to generate the high current, low voltages close to where they will be needed and to power the distributed power units with higher voltages and correspondingly reduced current levels.

DISTRIBUTION SYSTEM PLANNING

One of the essential elements in distribution system planning is the location of the load centre where the primary substation is situated. Establishment of load centre or primary substation, particularly in a densely populated area, must be prepared in long-term plan, for example, in a 10-year plan. The outlets from the primary substation will then supply the required electrical energy to the nearby customer loads. Customer substations will then further transform the distribution high voltage to the LV. (LV refers to the voltage below 1000V).

1. Basic Design Criteria –

Distribution network refers to those 22kV or llkV network supplying electricity to customers through cable or Overhead Line (OHL). From primary substation to various customer substations, various types of network configurations are possible, for example, single-end fed. double-end fed and closed ring network arrangement. In the customer substation, it normally consists of the step down transformer to LV: it may also contain HV circuit breaker(s). ring main units. Additional consideration is the availability of remote control facilities to enhance the security of supply.

In transmission network, the typical design concept is the 'N-T reliability application. SN-1' is referred to as any single component failure in the supply network will not affect the electricity supply. Hence in the case of a failure of a transmission line, or a transformer connected to the distribution primary substation from the transmission source, the supply to the distribution network will not be affected. It is normally achieved with suitable protection and associated inter-tripping or switching scheme to the distribution incoming from the transmission network. Hence, the primary substation is thus designed to supply a firm load based on the calculation of 'N-1' criteria.

On the other hand, the distribution network connected from the primary source substation will depends on the geographical locations of the customer substations. There are two major types of distribution networking:

Single-end radial fed - Single-end radial fed refers to a number of customer substations or pole-mounted substations are connected to the primary substation. The supply security is the lowest as any single point failure will result in the loss of supply to the customer substation.
Similarly, any single failure in the customer substation will result in loss of supply to the customer. In case of fault, the supply restoration will depend on the fault repair time.

Double-end fed with an NO point - To provide a higher supply security- the customer substations can be fed from two sources as shown in Figure 3.

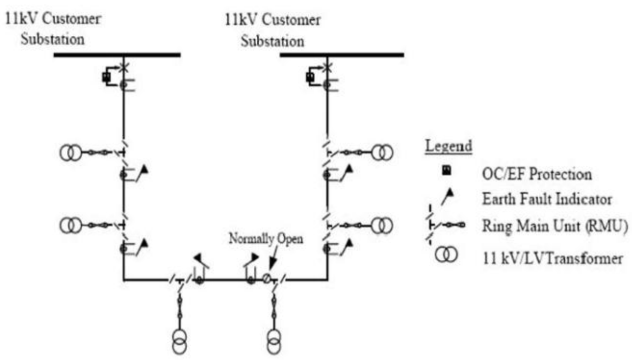

Figure 3. Typical 1 lkV RMU open ring arrangement
The customer substation is normally supplied from a single end and in the case of loss of supply from the one source end. for example due to a component failure, the NO (normally open) point can be closed to restore supply after the faulty portion of the component is isolated. The supply restoration will be quicker and is not directly depended on the fault repair time. The customer substation may consist of Rain Main Unit (RMU) and equipped with earth fault indicator as shown below. This configuration provides less secure supply since most of RMU only equipped with isolators which is unable to break fault current. This results in loss of supply in case of fault in the RMU circuit since the controlling circuit breaker at the controlling/customer substation will trip to isolate the faulty circuit.

2. Network Configuration -

Distribution network refers to those 22kV or llkV network supplying electricity to customers through cable or Overhead Line (OHL). The network configuration would directly affect the supply reliability. Of the three types of configuration, the closed ring configuration provides the highest possible supply reliability. Each customer substation has dual supply and so a single circuit fault would not cause any supply interruption. It is. in fact, aligned with "N-l" approach. In the ring configuration, each feeder is protected by either high-speed feeder protection or pilot wire protection with back up overcurrent and earth fault (OC/EF) protection equipped in the primary substation.

Generally, the number of outgoing feeders of a closed ring form primary substation is up to 4. since the more the number of outgoing feeder, the lower the fault current to be shared by each feeder. This would cause difficulty for the backup OC/EF protection to operate in case of malfunction of switchgear in customer substations. When the number of outgoing feeder is higher than 4. more loading will be supplied and the corresponding effect in the case of loss of supply will be much increased hence more legged closed ring is not preferred.

The Maximum Current Rating of llkV cable is 7MVA and so the capacity of 4-legged closed ling should be 28MVA. However, with the "N-r"[1] approach to the system reliability, the closed ring should be able to cater for the loss of one of the outgoing feeders from primary substation. That is to say. the remaining 3 feeders would take up the load due to the loss of the outgoing feeder. In order not to overload the outgoing feeders, the firm capacity of a 4-legged closed ring is limited to 21MVA.

3. Reliability Considerations -

Network security refers to the ability of a power system to continuously supply electricity to customers. Network security can be measured in terms of number of interruptions in a given period or the average duration of interruptions. It should be pointed out that the network security is always proportional to its cost. Thus, it is important to strike a balance between network security and cost incurred so that cost effectiveness can be attained.

Generally, the supply to each customer is capable to meet the customer's peak load. When there is a fault occurred in the network, the supply may be interrupted depending on the location of fault and the network arrangement.

As the power is transmitted from high voltage (500kV. 400kV or 132kV) to low voltage (llkV or 380V). the impact of fault would become smaller in terms of load loss magnitude or number of affected customers. In order to prevent widespread load loss, different supply security arrangements are adopted to different load group according to their size.

APPLICATIONS FOR DISTRIBUTED POWER

While we may not often think of power utilities in the same context with electronic systems. The most obvious example of distributed power is our nationwide 60 Hertz power grid. Clearly the problems of distributing 110Vac power over hundreds of miles would be insurmountable were it not for the distributed network of step down transformers to process the power from much higher transmission voltage levels to household values.

Smaller examples where power is used at some distance from its point of generation can be seen in ships and airplanes where power is distributed at higher voltage levels and converted at locations closer to the point of use. These applications. Like the utilities. are typically designed for ac transmissions where the local power processor involves a 60 or 400Hz transformer. a relatively bulky item. It is interesting to note that a similar technique was initially proposed for the Space Station but with the transmission frequency changed to 20kHz to reduce the size and weight of the line transformers. While an interesting concept. this approach suffered (perhaps fatally) from problems associated with EMI generation and power factor control.

The most obvious example of distributed power in electronic systems is in telecommunications where the initial use of -48V batteries as power backup has led to the standardized application of a 48V dc distribution bus for all types of telecommunication equipment. much of it now digital systems operating from SV power.

Both military and space systems have had an ongoing need for distributed power systems dictated by the need for reliability rather than distribution efficiency. To aid in this effort. the various defense organizations have spent millions to fund the development of very dense and reliable standard DC/DC power conversion modules.

Certainly large computer systems are prime candidates for distributed power due to their large usage of low voltage power. As logic voltage levels drop below SV. this need to process the power at the point of use will be almost mandatory .While a lf2 Volt drop in the power distribution lines is a costly 10% loss at SV. it becomes an unacceptable waste at three volts and lower.

Those familiar with automotive systems are aware of significant power distribution problems as ever-increasing quantities of electronic components are connected to the 12V battery. It has been accepted as a given eventuality that cars will soon have to be equipped with 24V batteries. This will surely spawn a need for local down converters distributed throughout the automobile.

CONCLUSION

With the present rapid development of all types of power processing module architectures, it seems clear that distributed power is the wave of the future for a broad range of power levels. Much has been accomplished in standardizing on bus voltage levels, improving the efficiency of the modules, and reducing their costs. Additional benefits of standardized packages, high-reliability qualified designs, and competitive vendors provide even greater emphasis that distributed power is an attractive and viable solution to the system power design problem.

REFERENCES

- Canadian Electrical Association. *Connecting Small Generators to Utility Distribution Systems*. 128 D 767. A.B. Sturton Consultants Inc. and Acres International Ltd, June 1994.
- Carsten, Bruce, "Distributed Power Systems of the Future Utilizing High Frequency Converters," HFPC Proceedings. April, 1987.
- IEEE Standards Coordinating Committee 21. *IEEE P1547 Draft 7 Draft Standard for Interconnecting Distributed Resources with Electric Power Systems*. New York: Institute of Electrical and Electronics Engineers Inc., February 2001.
- Jordan, Mark, "Load Share IC Simplifies Parallel Power Supply Design," PCIM Proceedings. September 1991.
- M. N. Marwali, Jin-Woo Jung, A. Keyhani, "Control of Distributed Generation Systems - Part II: Load Sharing Control", IEEE Trans-

action on Power Electronics, November 2004., Vol. 19, No. 6, pp. 1551- 1561.

- Wildrick, C.M., et al, " A Systematic Procedure to Generate Load Impedance Specifications in Distributed Power Systems", Virginia Power Electronics Center, V.P.I., Blacksburg, VA 24(X)1.