Selection of Optimal Location and Size of Multiple Distributed Generations by Using Kalman Filter Algorithm

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ABSTRACT

This project presents way of properly selecting the location and size of multiple distributed generations. The approach which is used here is Kalman filter algorithm. Increase in power consumption can cause serious stability problems in electric power systems if there are no ongoing or impending construction projects of new power plants or transmission lines. Additionally, such increase can result in large power losses of the system. In costly and environmentally effective manner to avoid constructing the new infrastructures such as power plants, transmission lines, etc., In response to the recently increased prices of oil and natural gas, it is expected that the electric power industry will undergo considerable and rapid change with respect to its structure, operation, planning, and regulation. Moreover, because of new constraints placed by economical, political, and environ-mental factors, trends in power system planning and operation are being pushed toward maximum utilization of existing electricity infrastructure with tight operating margins. Therefore, the electric utility companies are striving to achieve this objective via many different ways, one of which is to defer the distributed generation (DG) solution by an independent power producer (IPP) to meet growing customer load demand the distributed generation (DG) has been paid great attention so far as a potential solution for these problems. The beneficial effects of DG mainly depend on its location and size. Therefore, selection of optimal location and size of the DG is a necessary process to maintain the stability and reliability of existing system effectively before it is connected to a power grid. However, the systematic and cardinal rule for this issue is still an open question. In this project, a method to determine the optimal locations of multiple DGs is proposed by considering power loss. Also, their optimal sizes are determined by using the Kalman filter algorithm.

Keywords **–** Distributed Generation, DG technologies, harmonics, voltage stability.

I. INTRODUCTION

1.1 DISTRIBUTED GENERATION

Distributed generation is an approach that employs small– scale technologies to produce electricity close to the end users of power. DG technologies often consist of modular (and sometimes renewable – energy) generators, and they offer a number of potential benefits. In many cases, distributed generators can provide lower. Cost electricity and higher power reliability and security with fewer environmental consequences than can traditional power generators. In contrast to the use of a few large- scale generating stations located far from load centers- the approach used in the traditional electric power paradigm. DG systems employ numerous, but small plants and can provide power onsite with little reliance on the distribution and transmission grid. DG technologies yield power in capacities that range from a fraction of a kilowatt (kW) to about 100 megawatts (MW). Utility – scale generation units generate power in capacities that often reach beyond 1,000 MW. As per the Government of India, decentralized power production facility is defined as any facility that produces power less than 100kW and is not connected to central grid. These are stand-alone systems that supply power to a particular commercial / domestic setup. Due to unavailability of grid the management of power produces is more difficult for such systems however there are no grid losses and voltage problems associated with it. These systems are characterized by an energy storage device in form of batteries. The storage also has capacity to run 24 hours of normal operation of the setup. Decentralized electricity has some very fundamental differences compared to centralized electricity production.

1.2. IMPACT OF DISTRIBUTED GENERATION

DG causes a significant impact in electric losses due to its proximity to the load centers. DG units should be allocated in places where they provide a higher reduction of losses. This process of DG allocation is similar to capacitor allocation to minimize losses. The main difference is that the DG units cause impact on both the active and reactive power, while the capacitor banks only have impact in the reactive power flow. In feeders with high losses, a small amount of DG strategically allocated (10-20% of the feeder load) could cause a significant reduction of losses.

- ¾ With the connection of DG in system power losses are reduced.
  ¾ For a particular DG capacity there is a location in the system such that if we connect

DG at that location power losses are minimum in comparison when same DG is connected at any other point.

- ¾ That particular location where power losses are minimum is known as Optimum location.

1.2.2. VOLTAGE PROFILE

The distribution systems are usually regulated through tap changing at substation transformers and by the use of voltage regulators and capacitors on the feeders. This form of voltage regulation assumes power flows circulating from the substation to the loads. Since the control of voltage regulation is usually based on radial power flows, the inappropriate DG allocation can cause low or over-voltages in the network. On the other hand, the installation of DG can have positive impacts in the distribution system by enabling reactive compensation for voltage control, reducing the losses, contributing for frequency regulation and acting as spinning reserve in main system fault cases. Under voltage and over voltage conditions can arise given the incompatibility of DG with the voltage regulation in radial power flows.

1.2.3. RELIABILITY

Customers in an economical and reliable manner. It is important to plan and maintain reliable power systems because cost of interruptions and power outages can have severe economic impact on the utility and its customers. Traditionally, reliability analysis and evaluation techniques at the distribution level have been far less developed than at the generation level since distribution outages are more localized and less costly than generation or transmission level outages. However, analysis of customer outage data of utilities has shown that the largest individual contribution for unavailability of supply comes from distribution system failure.

One of the main purpose of integrating DG to distribution system is to increase the reliability of power supply. DG can be used as a back-up system or as a main supply. DG will handle peak loads also.

1.3. PROJECT OVERVIEW

This project is organized as follows. In chapter 2, what are the different types of DG's are used and their benefits are explained in detail. In chapter3, literature survey for distributed generations. In chapter 4, mathematical modeling. For KALMAN FILTER is defined. In chapter 5, How to select the optimal locations and sizes of DG's are explained. Results are given in chapter 6. Conclusions are given in chapter 7.

II. TECHNOLOGIES OF DG's AND ITS BENEFITS

2.1. TECHNOLOGIES

Distributed generation takes place on tow – levels: the local level and the end – point level. Local level power generation plants often include renewable energy technologies that are site specific, such as wind turbines, geothermal energy production, solar systems (photovoltaic and combustion), and some hydro – thermal plants. These plants tend to be smaller and less centralized than the traditional model plants. They also are frequently more energy and cost efficient and more reliable. Since these local level DG producers often take into account the local context, the usually produce less environmentally damaging or disrupting energy than the larger central model plants. Phosphorus fuel cells also provide an alternative route to a DG technology. These are not as environmentally reliant as the previously mentioned technologies. These fuel cells are able to provide electricity through a chemical process rather than a combustion process. This process produces little particulate waste.

Fig-1 Wind turbines at buffalo mountain, TN

Fig-2 Photovoltaic (solar) panels

Fig-3 A 300KW Micro-turbine at Oak Ridge National Laboratory, TN

At the end – point level the individual energy consumer can apply many of these same technologies with similar effects. One DG technology frequently employed by end- point users is the modular internal combustion engine. For example, some departments are use these power generators as a backup to the normal power grid. These modular internal combustion engines can also be used to backup RVs and homes. As many of these familiar examples show DG technologies can operate as isolated "Islands" of electric energy production or they can serve as small contributors to the power grid.

2.2. BENEFITS OF DISTRIBUTED GENERATION

In the last decade, the concept of many small scale energy sources dispersed over the grid gain a considerable interest. Most of all, technological innovations and a changing economic and regulatory environment were that main triggers for this interest. International Energy Agency IEA lists five major factors that contribute to this evolution, such as developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate change. Especially the last two points seem to offer the most significant benefits, as it is unlikely that distributed generation would be capable of avoiding the development of new transmission lines. At minimum, the grid has to be available as backup supply. In the liberalized market environment, the distributed generation offers a number of benefits to the market participants. As a rule, customers look for the electricity services best suited for them. Different customers attach different weights to features of electrical energy supply, and distributed generation technologies can help electricity suppliers to supply the type of electricity service they prefer. One of the most interesting features is the flexibility of DG that could allow market participants to respond to changing market conditions, i.e. due to their small sizes and the short construction lead times compared to most types of larger central power plants.

Benefits	Costs
Airborne or Outdoor Emissions	Utility Revenue Reduction
Reliability and Power Quality (Distribution System) Enhanced Electricity Price Elasticity	Standby Charges
Avoided T&D Capacity	Incentives for Clean Technologies
System Losses	Maintain System Reliability & Control DER
Ancillary Services	Emissions Offsets
	Airborne or Outdoor Emissions
	DER Fuel Delivery Challenges

DG Benefits Definitions		
1	Support of RPS Goals	The value of allowing a utility to meet renewable portfolio standards by having renewable DG
2	Mitigation of Market Power	The value to the system from reducing output from high marginal production cost plants, mitigating capacity shortages and countering the seller's market power
3	Airborne or Outdoor Emissions	The economic incentives to owners of clean DG technologies and the reduced health risks to society. The pattern of emissions from outdoor or airborne pollutants such as NOx, SO2, and others from clean DG units that are less hazardous than emissions of the conventional plants that DG replaces.
4	Reduced Security Risk to Grid	The value of reducing the reliance on the central grid, making the grid a less appealing terrorist target and reducing the impact of other grid disruptions
5	Reliability and Power Quality (Distribution System)	The value to the utility of avoiding outage costs and improving the quality of the power at or near customer sites

6	Voltage Support to Electric Grid	The value to the utility of providing voltage/VAR control. Small-scale generation in the distribution system can support voltage by injecting reactive power thereby improving power quality and lowering losses.
7	Enhanced Electricity Price Elasticity	The value of increasing the elasticity of electric demand, which will tend to lower prices to the benefit of all consumers.
8	NIMBY Opposition to Central Power Plants and Transmission Lines	The value of reducing the "Not in my back yard" sentiment towards the siting of new power plants. Opposition to small scale onsite facilities is likely to be less of an impediment to development of DG than of central stations.
9	Land Use Effects	The value of reducing "foot-print" or space needed by generation, transmission and distribution infrastructure
10	Avoided T&D Capacity	The financial value of avoiding or deferring a capital investment in transmission and distribution system capacity
11	System Losses	The value of the energy saved through reduced resistive system losses. Energy is lost when it is transmitted through wires. The larger the distance, the more the losses are. Sitting small-scale generation close to load lowers losses
12	Combined Heat and Power/ Efficiency Improvement	The monetary savings from utilizing waste heat from the DG in customer applications to meet heating or cooling needs, increasing overall efficiency of energy use

DG Benefits Definitions		
13	Consumer Control	The value of allowing customers to control their energy source and avoid dependence on a large centrally controlled system
14	Lower Cost of Electricity	The difference for a customer between the cost of purchasing electricity and the cost of generating electricity onsite
15	Consumer Electricity Price Protection	The value for customer of having the ability to lock-in prices for their energy requirements for the long term
16	Reliability and Power Quality (DG Owner)	The value to the customers with sensitive loads of avoiding outages and improving the quality of their power
17	Ancillary Services	The value of providing spinning reserve, regulation, or other ancillary services

Table-1 DG Benefits Definitions

2.3. OBJECTIVES FOR DG's

Increase in power consumption can cause serious stability problems in electric power systems if there are no on – going or impending construction projects of new power plants or transmission lines. Additionally, such increase can result in large power losses of the system. In costly and environmentally effective manner to avoid constructing the new infrastructures such as power plants, transmission lines, etc. the distributed generation (DG) solution by an independent power producer (IPP) to meet growing customer load demand. In this case, deferral credits received by the IPP depend on the incremental system reliability improvement made by the DG solution. The DG is based on the renewable energy sources such as fuel cell, photovoltaic, and wind power as well as combined heat and power gas turbine, micro-turbine, etc. Now, it becomes an important integral component of the modern power system in installing the DG to an electric power grid is not a simple plug – and – play problem. Indeed, as well as operation of the DG itself, it requires a careful consideration for the interaction with existing power network with respect to stability reliability, protection coordination, power loss, power quality issues, etc. first of all, it is important to deter – mine the optimal location and size of a given DG before it is connected to a power system. Moreover, if multiple DGs are installed, an optimal approach for selection of their placement and sizing is imperative in order to maintain the stability and re- liability of an existing power system effectively. Nevertheless, the systematic and cardinal rules that define this issue remain an open question. This paper proposes a method to select the optimal locations of multiple DGs by considering total power loss in a steady – state operation. Thereafter, their optimal sizes are determined by using the Kalman filter algorithm.

2.3.1 FLEXIBILITY IN PRICE RESPONSE

Important aspects of the abovementioned flexibility of distributed generation technologies are operation, size and expandability. Flexible reaction to electrical energy price evolutions can be one of the examples, allowing a DG to serve as a hedge against these price fluctuations. Apparently, using distributed generation for continuous use or for peak shaving is the major driver for the US demand for distributed generation. In Europe, market demand for distributed generation is driven by heat applications, the introduction of renewable and by potential efficiency improvements.

2.3.2. FLEXIBILITY IN RELIABILITY NEEDS

Reliability considerations of the second major driver of US demand for distributed generation is quality of supply or reliability considerations. Reliability problems refer to sustained interruptions in electrical energy supply (outages). The liberalization of energy markets makes customers more aware of the value of reliable electricity supply. In many European countries, the reliability level has been very high, mainly because of high engineering standards. High reliability level implies high investment and maintenance costs for the network and generation infrastructure. Due to the incentives for cost-effectiveness that come from the introduction of competition in generation and from the re-regulation of the network companies, it might be that reliability levels will decrease. However, for some industries, such as chemical, petroleum, refining, paper, metal, telecommunication, a reliable power supply is very important. Such companies may find the reliability of the grid supplied electricity too low and thus be willing to invest in distributed generation units in order to increase their overall reliability of supply. The IEA recognizes the provision of reliable power as the most important future market niche for distributed generation. Fuel cells and backup systems combined with an UPS (Uninterruptible Power Supply) are identified as the technologies that could provide protection against power interruptions, though it has to be noted that the fuel cell technology is currently not easily commercially available.

2.3.3. FLEXIBILITY IN POWER QUALITY NEEDS

Apart from large voltage drops to near zero (reliability problems), one can also have smaller voltage deviations. The latter deviations are aspects of power quality. Power quality refers to the degree to which power characteristics align with the ideal sinusoidal voltage and current waveform, with current and voltage in balance. Thus, strictly speaking, power quality encompasses reliability. Insufficient power quality can be caused by failures and switching operations in the network (voltage dips and transients) and by network disturbances from loads (flickers, harmonics and phase imbalance).

2.3.4. ENVIRONMENTAL FRIENDLINESS

Environmental policies or concerns are probably the major driving force for the demand for distributed generation in Europe. Environmental regulations force players in the electricity market to look for cleaner energy- and cost-efficient solutions. Many of the distributed generation technologies are recognized environmentally friendly. Combined Heat and Power (CHP) technology, allowing for portfolio optimization of companies needing both heat and electrical energy, is one of the examples. Compared to separate fossil-fired generation of heat and electricity, CHP generation may result in a primary energy conservation, varying from 10% to 30%, depending on the size (and efficiency) of the cogeneration units. The avoided emissions are in a first approximation similar to the amount of energy saving. Furthermore, as renewable energy sources are by nature small-scale and dispersed over the grid. Installing distributed generation allows the exploitation of cheap fuel opportunities. For example, DG units could burn landfill gasses in the proximity of landfills, or other locally available biomass resources. Most government policies that to promote the use of renewable will also result in an increased impact of distributed generation.

2.3.5. FINANCIAL IMPACT

As the electricity needs of the society increased, larger power plants were built away from civilization. To transfer electricity complex transmission and distribution channel was also built. These large power plants gave economies of scale and hence became more economic in the context of the technology. Today, the presence of smaller generation technologies has changed the thinking. Technologies such as the combustion turbine, reciprocating engine, fuel cell, and photovoltaic are small-scale technologies that can be used at or on a site close to the end user. Technology has advanced to the point where there is less of a need to build large, expensive power stations when extra capacity is needed—economies of scale is no longer a viable argument for building large power plants.

Decentralized power plants are actual plants employing central plant generation technologies that are located near users. These combined heat and power (CHP) plants achieve 65%-97% net electrical efficiency by recycling normally wasted heat, and by avoiding transmission and distribution losses. Waste of energy from the worldwide electricity system is around 67%. Most of the losses are from central thermal plants that cannot recover and use the waste heat. Considerable losses also arise from transmission of the energy from producer to consumer.

Looking to such a widespread deficit of supply compared to demand, it would be worthwhile considering whether we should duplicate energy transmission infrastructure all over the country – i.e. one gas pipeline network and electricity transmission and distribution network. In fact, instead of thinking of gas based mega power projects which will be prone to lot of T&D losses before the generated power could actually reach the consumer, it would be prudent to set up a widespread gas transmission and distribution network and set up a number of localized small and medium size power plants. It is important to consider the cost of power delivered rather that generated (Generation plus Transmission and distribution cost seen together). When seen from this perspective, the fallacy of the economy of scale argument in favor of Mega Power Projects will be obvious. A sample calculation was carried out to compare the economics of centralized mega power plants.

	Centralized Generation CCP 2500 MW	Distributed generation (all figures in Crores) CCHP 2100 MW	Distributed Generation with CCP 2100 MW
Delivered Power	2000 MW	2000 MW	2000 MW
Generation	10,000	10,500	10,500
Incremental T&D	10,000	1,050	1,050
Total Capital Cost	20,000	11,550	11,550
Fuel Cost for 20 Years	58,800	24,696	49392
Total life time cost for 20 years Operation	78,800	36,246	60,942
Unit cost of Generation	Rs. 4338/MWHR	Rs. 2216/MWHR	Rs. 2,988/MWHR

Assumptions :

Capital Cost

Centralized Generation Rs. 4 Crores / MW

Distributed Generation Rs. 5 Crores / MW

T&D Losses

Centralized Generation 20%

Distributed Generation 5%

Fuel Consumption

Centralized Generation – CCP - 210 NM3/MWHR

Distributed Generation – CCP - 210 NM3/MWHR

Distributed Generation – CCHP 105 NM3/ MWHR

Large central power plants cost less to build than smaller local power plants, but:

- One new KW delivered from central power plants requires 1.5 kW new plant 5,500 Rupees) and 1.5 KW new T&D, (87,000 Rupees); total of 142,000 Rupees

One new kW delivered from DG requires 1 kW new generation (50,000 Rupees) plus 0.1 kW new T&D (3,700 Rupees); total of 53,700 Rupees per delivered kW.

II. Headings

IV. LITERATURE SURVEY ON DG

3.1. CLASSIC ELECTRICITY PARADIGM

Central Power Station Model

The current model for electricity generation and distribution is dominated by centralized power plants. The power at these plants is typically combustion (coal, oil, and natural) or nuclear generated. Centralized power models, like this, require distribution from the center to outlying consumers. Current substations can be anywhere from 10s to 100s of miles away from the actual users of the power generated. This requires transmission across the distance.

This system of centralized power plants has many disadvantages. In addition to the transmission distance issues, these systems contribute to greenhouse gas emission, the production of nuclear waste, inefficiencies and power loss over the lengthy transmission lines, environmental distribution where the power lines are constructed, and security related issues.

Many of these issues can be mediated through distributed energies. By locating, the source near or at the end – user location the transmission line issues are rendered obsolete. Distributed generation (DG) is often produced by small modular energy conversion units like solar panels. As has been demonstrated by solar panel used, these units can be stand – alone or integrated into the existing energy grid. Frequently, consumers who have installed solar panels will contribute more to the grid than they take out resulting in a win – win situation for both the power grid and the end – user.

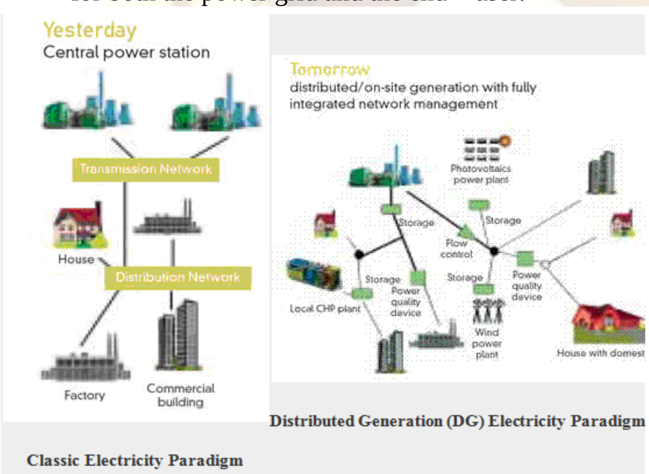

Fig-4 Electricity paradigm for DG

3.2. NEED OF DISTRIBUTED GENERATION

In the introduction, it was mentioned that the IEA identifies 5 major factors that contribute to the renewed interest in distributed generation. We feel that these five factors can be further reduced to two major driving forces, i.e. electricity market liberalization and environmental concerns. The developments in distribution technologies have been around for a long time, but were as such not capable of pushing the "economy as scale" out of the system. We doubt that distributed generation is capable of postponing, and certainly not of avoiding, the development of new transmission lines: at the minimum the grid has to be available as backup supply. The third element, being reliability, is at this moment not an issue in the interconnected European high voltage system, although this may change rapidly in the following years.

3.3. THE LIBERALIZATION OF ELECTRICITY MARKETS

There is the increased interest by electricity suppliers in distributed generation because they see it as a tool that can help them to fill in niches in a liberalized market. In such a market, customers will look for the electricity service best suited for them. Different customers attach different weights to features of electricity supply, and distributed generation technologies can help electricity suppliers to supply to the electricity customers the type of electricity service they prefer. In short, distributed generation allows players in the electricity sector to respond in a flexible way to changing market conditions. Some major examples are discussed below. In liberalized markets, it is important to adapt to the changing economic environment in the most flexible way. Distributed generation technologies generally provide this flexibility because of their small sizes and the short construction lead times compared to most types of larger central power plants. According to the IEA (2002), the value of their flexibility is probably understated when economic assessments of distributed generation are made. It should be stated that the lead time reduction is not always that evident. Public resistance to for instance wind energy and use of landfill gasses may be very high.

3.4. STAND BY CAPACITY OR PEAK USE CAPACITY

Many distributed generation technologies are indeed flexible in several respects: operation, size and expandability. For example, making use of distributed generation allows reacting in a flexible way to electricity price evolutions. Distributed generation then serves as a hedge against these price fluctuations. Apparently, the US demand for distributed generation is mainly driven by price volatility, i.e. using distributed generation for continuous use or for peaking use (peak shaving). In Europe, market demand for distributed generation is, for the moment, driven by heat applications, introduction of renewable and by potential efficiency improvements. These will be discussed below.

3.5. RELIABILITY AND POWER QUALITY

The second major driver of US demand for distributed generation is quality of supply considerations. Reliability problems refer to sustained interruptions, which are voltage drops to near zero (usually called outages), in electricity supply. The liberalization of energy markets makes customers more aware of the value of reliable electricity supply. In many European countries, the reliability level has been very high, mainly because of high engineering standards. Customers do not really care about supply interruptions because they do not feel it as a great risk. This can change in liberalized markets, because a high reliability level implies high investment and maintenance costs for the network and generation infrastructure. Because of the incentives for cost-effectiveness that come from the introduction of competition in generation and from the re-regulation of the network companies, it might be that reliability levels will decrease. However, having a reliable power supply is very important for industry (chemicals, petroleum, refining, paper, metal, telecommunications…). Firms in these industries may find the reliability of the grid supplied electricity too low and they will decide to invest in distributed generation units in order to return their overall reliability of supply to present, pre-liberalized standards. The IEA (2002) recognizes the provision of reliable power as the most important future market niche for distributed generation. It identifies two distributed generation technologies that could provide protection against power interruptions, i.e. fuel cells and backup systems combined with a UPS system (uninterruptible power supply). Also gas- and diesel engines combined with a fly- wheel to cover the start-up time are being commercialized. The reliability issue is rather new in Europe, contrary to the US, where a significant amount of research has been done on this issue. It has to be stressed that fuel cell technology is not easily commercially available. Apart from large voltage drops to near zero (reliability problems), one can also have smaller voltage deviations. The latter deviations are aspects of power quality. Power quality refers to the degree to which power characteristics align with the ideal sinusoidal voltage and current waveform, with current and voltage in balance. Thus, strictly speaking, power quality encompasses reliability. Insufficient power quality can be caused by (1) failures and switching operations in the network, which mainly result in voltage dips, interruptions, and transients; and (2) network disturbances from loads that mainly result in flicker (fast voltage variations), harmonics, and phase imbalance. The nature of these disturbances is related to the ‘short-circuit capacity’, being a measure for the internal impedance, in the network, which depends on the network's internal configuration (e.g., length of the lines, short-circuit capacity of generators and transformers, etc.). To protect the system from degradation in power quality, it is important for network operators to guarantee a specified minimum short-circuit capacity. The relation between distributed generation and power quality is an ambiguous one. On the one hand, many authors stress the healing effects of distributed generation for power quality problems. For example, in areas where voltage support is difficult, distributed generation can contribute because connecting distributed generation generally leads to a rise in voltage in the network (IEA (2002)).

large-scale introduction of decentralized power generating units may also lead to an instability of the voltage profile: due to the bi-directional power flows and the complicated reactive power flows arising when insufficient control is introduced, the voltage throughout the grid may fluctuate. Additionally, bi-directional power flows make it difficult to tune the protection systems in the grid: short-circuits and overloads are supplied by multiple sources, each independently not detecting the anomaly. Eventually an ‘islanding’ situation may occur in which a local generator keeps a part of a disconnected grid energized leading to dangerous situation for the repair personnel coming. Others also stress the potential negative externalities on power quality caused by the installation of distributed generation capacity.

3.6. ALTERNATIVE TO EXPANSION OR USE OF THE LOCAL NETWORK

Distributed generation could serve as a substitute for investments in transmission and distribution capacity (demand for distributed generation from T&D companies) or as a bypass for transmission and distribution costs (demand for distributed generation from electricity customers). Of course, this is possible only to the extent that alternative primary fuels are locally available. Furthermore, increased use of distributed generation can result in new congestion problems in other networks, such as for example the gas transport network. According to the IEA (2002), on-site production could result in cost savings in transmission and distribution of about 30% of electricity costs. As such, it is seen as one of the biggest potential drivers for the distributed generation demand. In general, the smaller the customer size, the larger the share of transmission and distribution costs in the electricity price (above 40% for households). From the point of view of the system operators, distributed generation units can substitute for investments in transmission and distribution capacity. In some cases, and with a different control, a distributed generation unit can even be used as an alternative to connecting a customer to the grid in a ‘stand alone’ application. Furthermore, well chosen distributed generation locations (i.e. close to the load) can also contribute to reduced grid losses. The IEA (2002) reports average grid losses of 6,8% in the OECD countries.

According to Dondi et al. (2002), cost savings of 10% to 15% can be achieved in this way. However, according to the AMPERE report (2000), these results are only correct when the distributed generation units are stand-alone units and don't appeal to the grid. If not they are jointly responsible for the distribution grid and its losses.

3.7. GRID SUPPORT

Finally, distributed generation can also contribute in the provision of ancillary services. These include services necessary to maintain a sustained and stable operation of the grid, but not directly supplying customers. This may be the capability to generate on demand of the grid operator, for instance to stabilize a dropping frequency due to a sudden under capacity (e.g. a power plant switching off due to technical problems) or excess demand.

3.8. DIFFICULTIES FOR DISTRIBUTED GENERATION

The question of power quality and distributed generation is not straightforward. On one hand, distributed generation contributes to the improvement of power quality. In the areas where voltage support is difficult, distributed generation offers significant benefits for the voltage profile and power factor corrections. On the other hand, large-scale introduction of decentralized power generating units may lead to instability of the voltage profile. The bi-directional power flows and the complex reactive power management can be problematic and lead to voltage profile fluctuation. Additionally, short-circuits and overloads are supplied by multiple sources, each independently not detecting the anomaly. Distributed generation (DG) solution by an independent power producer (IPP) to meet growing customer load demand . In this case, deferral credits received by the IPP depend on the incremental system reliability improvement made by the DG solution. The DG is based on the renewable energy sources such as fuel cell, photovoltaic, and wind power as well as combined heat and power gas turbine, micro-turbine, etc. Now, it becomes an important integral component of the modern power system in recent years for several reasons. For example, it is an electricity generation of small-scale size, which is connected to the customer's side in a distribution system. Therefore, it does not require additional infrastructure of huge power plant and trans- mission lines, but rather, reduces capital investments. In addition, it has a great ability for responding to peak loads quickly and effectively by the market forces or its associated IPPs. This results in improving the reliability of the system. Despite its promises, installing the DG to an electric power grid is not a simple plug-and-play problem. Indeed, as well as operation of the DG itself, it requires a careful consideration for the interaction with existing power network with respect to stability, reliability, protection coordination, power loss, power quality issues, etc. First of all, it is important to deter- mine the optimal location and size of a given DG before it is connected to a power system. Moreover, if multiple DGs are installed, an optimal approach for selection of their placement and sizing is imperative in order to maintain the stability and re- liability of an existing power system effectively. Nevertheless, the systematic and cardinal rules that define this issue remain an open question.

3.9. THE INFRASTRUCTURE OF A POWER SYSTEM

A power system is a large, complex integration of large generators, a transmission grid, distribution grids, distributed generators and loads, which are connected at points called busses. In describing the management of a power system we must define several components of the system:

- Physical assets – generators, loads and grids
- Asset owners – government, corporations and consumers
- Asset operators – public and private utilities, consumers
- Asset managers and energy markets – bi-lateral, wholesale, retail, ancillary – services markets and grid management
- Risk markets – financial risk portfolio managers, over – the – counter derivatives markets (OTC), commodity / derivative exchanges

Asset managers – public and private utilities, contractors, independent service operators (ISO).

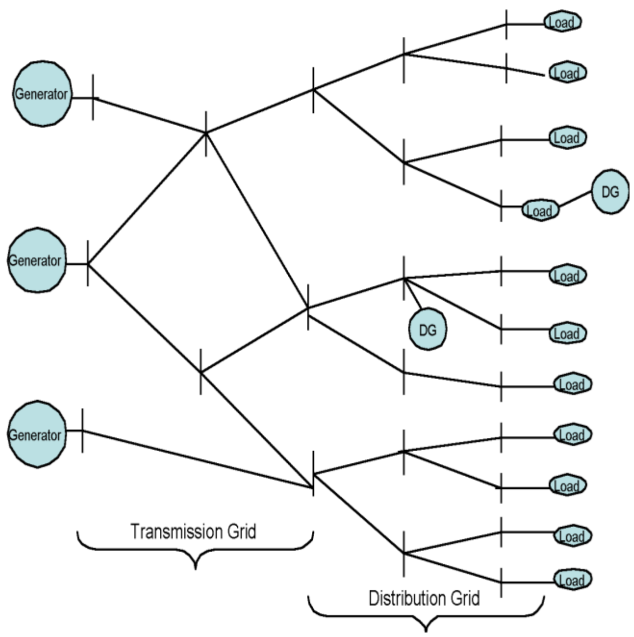

Fig-5 Power system assets

3.10. LOADS

A load is a demand for electric power. In power – grid management all loads are identified by the bus at which they connect to the distribution grid. There are three categories of loads: residential, commercial and industrial Residential load = the demand for electric power from home – owners, apartment dwellers and any other form of residence.

Commercial load = the demand for electric power from shopping malls, stores, government agencies and light business activities.

Industrial load = the demand for electric power from manufacturing facilities and other forms of heavy industry.

Most users of electricity do not purchase power directly from a generator. Instead they purchase power from a retailer. These retailers are known as load serving entities (LSE) or load aggregators. Retailers purchase power from wholesalers who, in turn, purchase power from suppliers. The actual delivery of electric power is sub – contracted to power – line owner / operators.

3.11. ISLANDED AND INTERCONNECTED DG

The source of electric power that is potentially nearest to a load is a small generator that is connected directly to the load and serves that load only. This kind of generation is called islanded distributed generation (DG). The qualifier “islanded” implies that this type of generator cannot deliver power to loads other that the one to which it is connected. Examples of islanded DG are small gas – turbine generators that provide power to commercial or industrial sites such as universities, shopping malls and refineries or clusters of residential loads such as apartment complexes. Other examples of islanded Dg are solar panels atop houses and buildings. In the management of a power grid, islanded DG has the effect of reducing the average load placed on the distribution grid as a DG unit can provide some or all of power required by the facility to which it is connected. However, the reliability of a DG unit has an effect on the variability of the load placed on the distribution grid as the shutdown of a DG unit suddenly transfers the facility’s demand for power from the DG unit to the distribution grid. Some distributed generators may be connected to the distribution grid in addition to a particular load. This kind of generation is called interconnected DG. The owner of an interconnected distributed generator may be able to use the power of this generator of the load to which it is connected as well as for sale to other loads within a distribution grid.

3.12. GENERATORS, IOU, PU

Most generation comes from large power plants, which are typically fueled by coal, fissionable radioactive elements or natural gas. Wind farms, hydroelectric generators, geothermal generators and other new generation technologies round out the portfolio of large- scale generation sources. These generators are owned and operated either by public utilities (PU) or private, investor owned utilities (IOU). Large generators are usually located long distances from the many loads that they serve. Consequently, large generators make their power available to transmission grids, which carry power from the generators over high – voltage power lines across large geographical areas.

3.13. TRANSMISSION GRIDS, BASIS POINTS, ISO

A transmission grid is a network of high – voltages power lines, transformers and busses that transfer electric power from large generators to distribution grids. A bus that connects a distribution gird to the transmission grid is called a basis point. A transmission grid covers a large geographical area and is connected to numerous large generation assets. The topology of the transmission grid is complex and allows for power to flow in each branch of the network in either direction as conditions require. Transmission grids are owned and operated by regulated business entities called independent service operators (ISO). ISO’s are responsible for ensuring that the transmission grid is maintained, all large generators have access to the grid and that all loads placed on the grid at basis points are supplied. Transmission grids are connected to one another to form a large power grid that can stretch across national regions and even international borders. Transferring large amounts of power from one transmission grid to another is a transaction known as wheeling.

3.14. DISTRIBUTION GRID

A conventional distribution grid is a network of low-voltage power lines, transformers and busses that bring electric power to loads within a small geographical area such as a small city, town or rural area within a county. The conventional topology of a distribution grid is arbores cent, which means that the power enters the gird at a basis point and is distributed to loads through successive branching. Each bus in such a network has one line that brings power into the bus and several lines that bring power away from the bus. The terminal points of a distribution grid are the loads that the grid supplies.

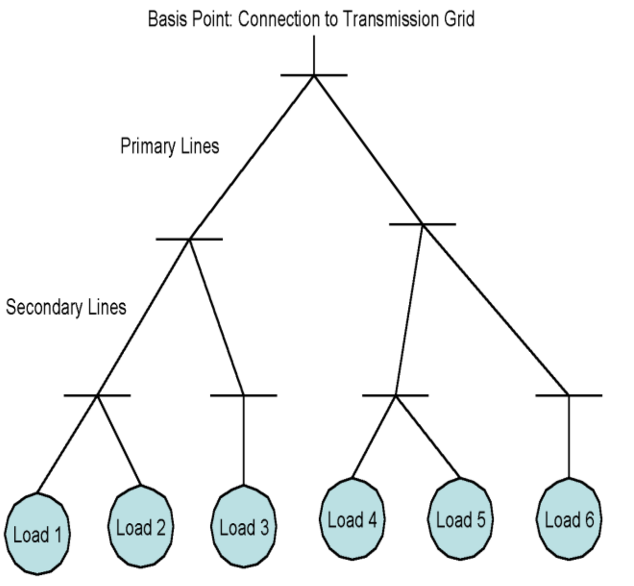

Fig-6 Distributed grid topology

Distribution grids are owned and operated by public utilities, cooperatives or investor – owned utilities that are granted monopoly rights over the grid's power distribution. These service organizations are responsible for the maintenance of the distribution gird.

The development of cost-effective DG has introduced two modifications to the conventional power grid.

- Islanded DG can reduce the load placed on the distribution grid at the discretion of the operator of the DG asset. Although the average load placed on the distribution grid is reduced by islanded DG, the volatility of this load may be increased due to the uncertainty in the DG operation.
- Interconnected DG can inject power into the distribution grid. This injection supplants some of the power that the distribution grid would purchase from the transmission grid. However, interconnected DG can cause power to flow in directions opposite to the conventional flow of power from the trunk of the distribution grid outward to the ends of the terminal branches.

3.15. ADVANTAGES OF DECENTRALIZED OVER CENTRALIZED IN INDIAN CONTEXT

Considering the unique demographical and geographical position of India and collating it with the current and the predicted future economic scenario of the country, we can say that decentralized electricity possess an edge over centralized electricity for the rural and off-grid electrification in India in the coming years.

- **Minimal losses :** India suffers from extremely high transmission and distribution loss. These losses account for 27% of the total electricity production of the nation. Decentralized production means that there are no grid losses and hence a huge portion of electricity that would be lost can be saved. Also, there won't be issues pertaining to grid related power evacuation or power management in decentralized production. For instance, if we need an effective power output of 5000MW from centralized power facility, we must install at least the power capacity of 8000MW which will also account for all the losses. But, the same power output can be generated by installing 5500- 6000MW in decentralized power facility.
- **Cogeneration:** Cogeneration is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. Centralized production facilities are never located near the revenue area of the inhabited land and so it is not feasible to use to this extra heat energy for other purposes. A possible solution which allows us to utilize the otherwise waste energy is setting up plants in the proximity area where that heat can be utilized. Decentralized production facility sited close to inhabited area could then use their waste heat. Facilities sited close to or at industrial sites could use their waste heat for a variety of industrial processes.
- **Easier Set-up, Maintenance and Operation:** Unlike centralized power production, a large land mass is not required for decentralized production. Set-up and maintenance of decentralized energy facility requires more manpower per watt as compared to centralized production facility. Off-grid decentralized power production facility does not need complex controls for its operation and thus highly skilled labor is also not required. Hence, requirement of less skilled manpower would directly result in the decrease of unemployment in the area.
- **Opportunity for SMEs and entrepreneurs:** Indian SME's contribute only 8% to total GDP compared to world's average of 65%. SME's contribute 22% of the total employed population in India. Decentralized electricity would also ensure the use of locally available resources and enhance productivity and production of electricity. This provides an excellent opportunity for SMEs. They are expected to contribute 22% alone to the Indian economy in 2012. Thus creating new opportunities for SMEs would further help in escalating Indian economy.

3.16. DECENTRALIZED PRODUCTION BASED ON RENEWABLE ENERGY IN INDIA

Gas/fossil fuel can be a viable option for energy production, but setting up infrastructure for gas/fossil fuel supply over a wide region will be a huge infrastructure investment that will also take considerable time. Setting up decentralized power production facility based on RE can drastically reduce infrastructure investment which can then be transferred for subsidizing renewable energy production which will run on very less operation cost. It will also aid in solving the problem of India's heavy dependence on imported fossils. Decreasing its fossil fuel import bill and simultaneously increasing rural electrification can thus be tackled by decentralized renewable production of electricity. Different regions in India are endowed with a wide variety of resources that can be used as fuel. A large portion of coastal regions have a huge wind power potential. Many remote locations in the region of western desert, wind power can be employed to generate electricity and run irrigation pumps. India also possesses the highest potential in the world to harness solar power and thus MNRE has recognized solar power as a major source of energy in future for India and has created ambitious plan in Jawaharlal Nehru National Solar Mission (JNNSM). JNNSM has also been integrated with RGVVY of Ministry of Power and RVE programme of MNRE. Wind and Solar power resources complement each other perfectly in Indian climatic cycle. Wind-solar hybrid systems can be very effective solutions.

V. MATHEMATICAL MODELING FOR KALMAN FILTER

4.1. THE STATE ESTIMATING PROCESS

The Kalman filter addresses the general problem of trying to estimate the state $x \in \Re^n$ of a discrete-time controlled process that is governed by the linear stochastic difference equation

$$x_k = Ax_{k-1} + Bu_{k-1} + w_{k-1}, \qquad (4.1)$$

with a measurement $z \in \Re^m$ that is

$$z_k = H \quad x_k + v_k \qquad (4.2)$$

The random variables w_k and v_k represent the process and measurement noise (respectively). They are assumed to be independent (of each other), white, and with normal probability distributions

$$p(w) \approx N(0,Q), \qquad (4.3)$$

$$p(v) \approx N(0,R), \qquad (4.4)$$

In practice, the process noise covariance Q and measurement noise covariance R matrices might change with each time step or measurement, however here we assume they are constant. The n x n matrix A in the difference equation (4.1) relates the state at the previous time step k – 1 to the state at the current step k , in the absence of either a driving function or process noise. Note that in practice *A* might change with each time step, but here we assume it is constant. The *n* x *l.*

4.2. THE COMPUTATIONAL ORIGINS OF THE FILTER

We define $\hat{x}_k^- \in \Re^n$ (note the "super minus") to be our a priori state estimate at step k given knowledge of the process prior to step k, and $\hat{x}_k^- \in \Re^n$ to be our a posteriori state estimate at step k given measurement z_k . We can then define a priori and a posteriori estimate errors as

$$e_k^- \equiv x_k - \hat{x}_k^-$$

$$e_k \equiv x_k - \hat{x}_k$$

The a priori estimate error covariance is then

$$P_k^- = E[e_k^- \, e_k^{-T}], \qquad (4.5)$$

and the a posteriori estimate error covariance is

$$P_k^- = E[e_k \quad e_k^T], \qquad (4.6)$$

In deriving the equations for the Kalman filter, we begin with the goal of finding an equation that Computes an a posteriori state estimate $\hat{x}$ as a linear combination of an a priori estimate $\hat{x}_{k-}$ and a weighted difference between an actual measurement z_k and a measurement prediction $H\hat{x}_k$ as shown below in (4.7). Some justification for (4.7) is given in "The probabilistic Origins of the Filter" found below.

$$\hat{x}_k = \hat{x}_k^- + K(z_k - H\hat{x}_k^-) \qquad (4.7)$$

The difference $(z_k - H\hat{x}_k)$ in (4.7) is called the measurement innovation, or the residual. The Residual reflects the discrepancy between the predicted measurement H $\hat{x}$ and the actual k Measurement z_k. A residual of zero means that the two are in complete agreement. The n x m Matrix K in (4.7) is chosen to be the gain or blending factor that minimizes the a Posteriori error covariance (4.6). This minimization can be accomplished by first substituting (4.7) into the above definition for e_k , substituting that into (4.6), performing the indicated expectations, taking the derivative of the trace of the result with respect to K, setting that result equal to zero, and then solving for K. One form of the Resulting K that minimizes (4.6)is given by

$$k_k = p_k^- H^T (HP_k^- H^T + R)^{-1}$$

$$= \frac{P_k^- H^T}{HP_k^- H^T + R} \qquad (4.8)$$

Looking at (8) we see that as the measurement error covariance R approaches zero, the gain K weights the residual more heavily. Specifically,

$$\lim_{Rk \to 0} Kk = H - 1 \quad (4.9)$$

On the other hand, as the *a priori* estimate error covariance P_k *approaches* zero, the gain *K* weights the residual less heavily. Specifically,

$$\lim_{Pk \to 0} Kk = 0 \quad (4.10)$$

All of the Kalman filter equations can be algebraically manipulated into to several forms. Equation (4..8) represents the Kalman gain in one popular form.

Another way of thinking about the weighting by K_k is that as the measurement error covariance R Approaches zero, the actual measurement z_k is "trusted" more and more, while the predicted measurement $H\hat{x}_k$ is trusted less and less. On the other hand, as the a priori estimate error Covariance P_k Approaches zero the actual measurement z_k is trusted less and less, while the predicted measurement $H\hat{x}_k$.

4.3. THE PROBABILISTIC ORIGINS OF THE FILTER:

The justification for (4.7) is rooted in the probability of the a priori estimate $\hat{x}_k$ conditioned on all prior measurements z_k (Bayes' rule). For now let it suffice to point out that the Kalman filter maintains the first two moments of the state distribution,

$$E[x_k] = \hat{x}_k \quad (4.11)$$

$$E[(x_k - \hat{x}_k)(x_k - \hat{x}_k)^T] = P_k \quad (4.12)$$

The *a posteriori* state estimate (4.7) reflects the mean (the first moment) of the state distribution— it is normally distributed if the conditions of (4.3) and (4.4) are met. The *a posteriori* estimate error covariance (4.6) reflects the variance of the state distribution (the second non-central moment). In other words,

$$p(x_k / z_k) \approx N(E[x_k], E[(x_k - \hat{x}_k)(x_k - \hat{x}_k)^T])$$

$$= N(\hat{x}_k, P_k).$$

The time update projects the current state estimate ahead in time. The measurement update adjusts the projected estimate by an actual measurement at that time. The specific equations for the time and measurement updates are presented below.

Discrete Kalman filter time update equations.

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1} \quad (4.14)$$

$$P_k^- = AP_{k-1}A^T + Q \quad (4.15)$$

Again notice how the time update equations are (4.14) & (4.15) project the state and covariance estimates forward from time step *k* – 1 to step *k*. *A* and *B* are from (4.1), while *Q is* from (4.3). Initial conditions for the filter are discussed in the earlier references.

Discrete Kalman filter measurement update equations.

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \quad (4.16)$$

$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-) \quad (4.17)$$

$$P_k = (I - K_k H)P_k^- \quad (4.18)$$

The first task during the measurement update is to compute the Kalman gain, K_k. Notice that the equation given here as (4.16) is the same as (4.8). The next step is to actually measure the process to obtain z_k, and then to generate an a posteriori state estimate by incorporating the measurement as in (4.17). Again (4.2) is simply (4.7) repeated here for completeness. The final step is to obtain an a posteriori error covariance estimate via (4.18). After each time and measurement update pair, the process is repeated with the previous a posteriori estimates used to project or predict the new a priori estimates. This recursive nature is one of the very appealing features of the Kalman filter—it makes practical implementations much more feasible than (for example) an implementation of a Wiener filter [Brown92] which is designed to operate on all of the data directly for each estimate. The Kalman filter instead recursively conditions the current estimate on all of the past measurements. Figure 2 below offers a complete picture of the operation of the filter, combining the high-level diagram of Figure 1 with the equations from (4.14) to (4.15) and (4.16) to (4.18).

4.4. FILTER PARAMETERS AND TUNING

In the actual implementation of the filter, the measurement noise covariance R is usually measured prior to operation of the filter. Measuring the measurement error covariance R is generally practical (possible) because we need to be able to measure the process anyway (while operating the filter) so we should generally be able to take some off-line sample measurements in order to determine the variance of the measurement noise. The determination of the process noise covariance *Q* is generally more difficult as we typically do not have the ability to directly observe the process we are estimating. Sometimes a relatively simple (poor) process model can produce acceptable results if one "injects" enough uncertainty into the process via the selection of *Q*. Certainly in this case one would hope that the process measurements are reliable. In either case, whether or not we have a rational basis for choosing the parameters, often times superior filter performance (statistically speaking) can be obtained by tuning the filter parameters Q and R. The tuning is usually performed off-line, frequently with the help of another (distinct) Kalman filter in a process generally referred to as system identification.

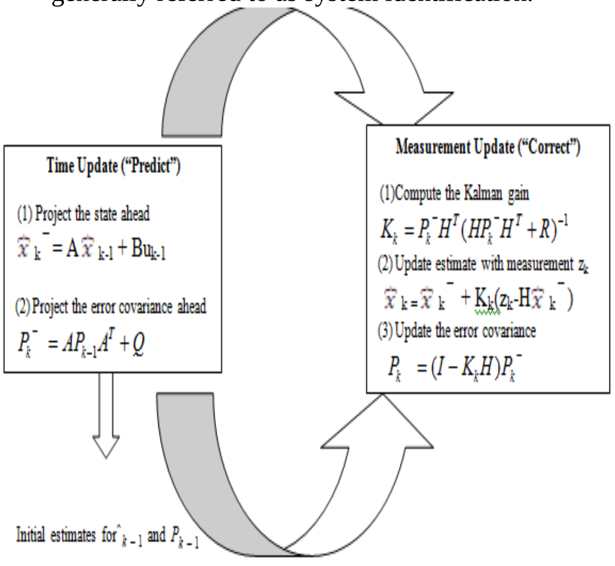

Fig-8 A complete picture of the operation of the Kalman filter combining the high-level diagram of Figure 7with the equations from (4.14-4.15) and (4.16-4.18).

In closing we note that under conditions where Q and R .are in fact constant, both the estimation error covariance P_k and the Kalman gain K_k will stabilize quickly and then remain constant (see the filter update equations in Figure 1-2). If this is the case, these parameters can be pre-computed by either running the filter off-line, or for example by determining the steady-state value of P_k as described. It is frequently the case however that the measurement error (in particular) does not remain constant. For example, when sighting beacons in our optoelectronic tracker ceiling panels, the noise in measurements of nearby beacons will be smaller than that in far-away beacons. Also, the process noise Q is sometimes changed dynamically during filter operation becoming Q_k in order to adjust to different dynamics.

I. SELECTION OF OPTIMAL LOCATIONS AND SIZES OF DG'S

The main aim of this project is to determine the optimal locations of multiple DGs is proposed by considering power loss. Also, their optimal sizes are determined by using the Kalman filter algorithm. it is expected that the electric power industry will undergo considerable and rapid change with respect to its structure, operation, planning, and regulation. Moreover, because of new constraints placed by economical, political, and environ- mental factors, trends in power system planning and operation are being pushed toward maximum utilization of existing electricity infrastructure with tight operating margins. Therefore, the electric utility companies are striving to achieve this objective via many different ways, one of which is to defer the distributed generation (DG) solution by an independent power producer (IPP) to meet growing customer load demand . In this case, deferral credits received by the IPP depend on the incremental system reliability improvement made by the DG solution. The DG is based on the renewable energy sources such as fuel cell, photovoltaic, and wind power as well as combined heat and power gas turbine, micro-turbine, etc. Now, it becomes an important integral component of the modern power system in recent years for several reasons . For example, it is an electricity generation of small-scale size, which is connected to the customer's side in a distribution system. Therefore, it does not require additional infrastructure of huge power plant and trans- mission lines, but rather, reduces capital investments. In addition, it has a great ability for responding to peak loads quickly and effectively by the market forces or its associated IPPs. This results in improving the reliability of the system. Despite its promises, installing the DG to an electric power grid is not a simple plug-and-play problem. Indeed, as well as operation of the DG itself, it requires a careful consideration for the interaction with existing power network with respect to stability, reliability, protection coordination, power loss, power quality issues, etc.. First of all, it is important to deter- mine the optimal location and size of a given DG before it is connected to a power system. Moreover, if multiple DGs are installed, an optimal approach for selection of their placement and sizing is imperative in order to maintain the stability and reliability of an existing power system effectively. This project determines a method to select the optimal locations of multiple DGs by considering total power loss in a steady-state operation. Thereafter, their optimal sizes are determined by using the Kalman filter algorithm.

5.1. SELECTION OF OPTIMAL LOCATION

5.1.1 REDUCTION OF POWER LOSS BY CONNECTING DG

In general, the existing power plants tend to be far from the consumption regions, and this situation causes a large amount of power loss on the power system. The IEEE benchmarked 30-bus system is shown in Fig.9. Where all loads can be classified under one of two classes. The first classification is the directly-connected-bus while the second is the load-concentration-bus. The directly-connected-bus is defined as a bus connected to a reference bus that does not pass through any other buses. For example, buses 12, 14, 18, and 23 in Fig. 3 are the directly-connected-buses if bus 15 is chosen as a reference bus. The load-concentration-bus handles relatively large loads, and is more connected to the other directly-connected-buses when compared to other nearby buses. In Fig. 9, buses 10, 12, 27, and5 can be selected as the representative load-concentration buses of Areas 1 through 4, respectively. When the DG is applied to this system, it is not desirable to connect each DG to every load bus to minimize power loss. Instead, the multiple representative DGs can be connected to the load-concentration-buses. Then, they provide an effect similar to the case where there are all DGs on each load bus, but with added benefit of reduced power loss.

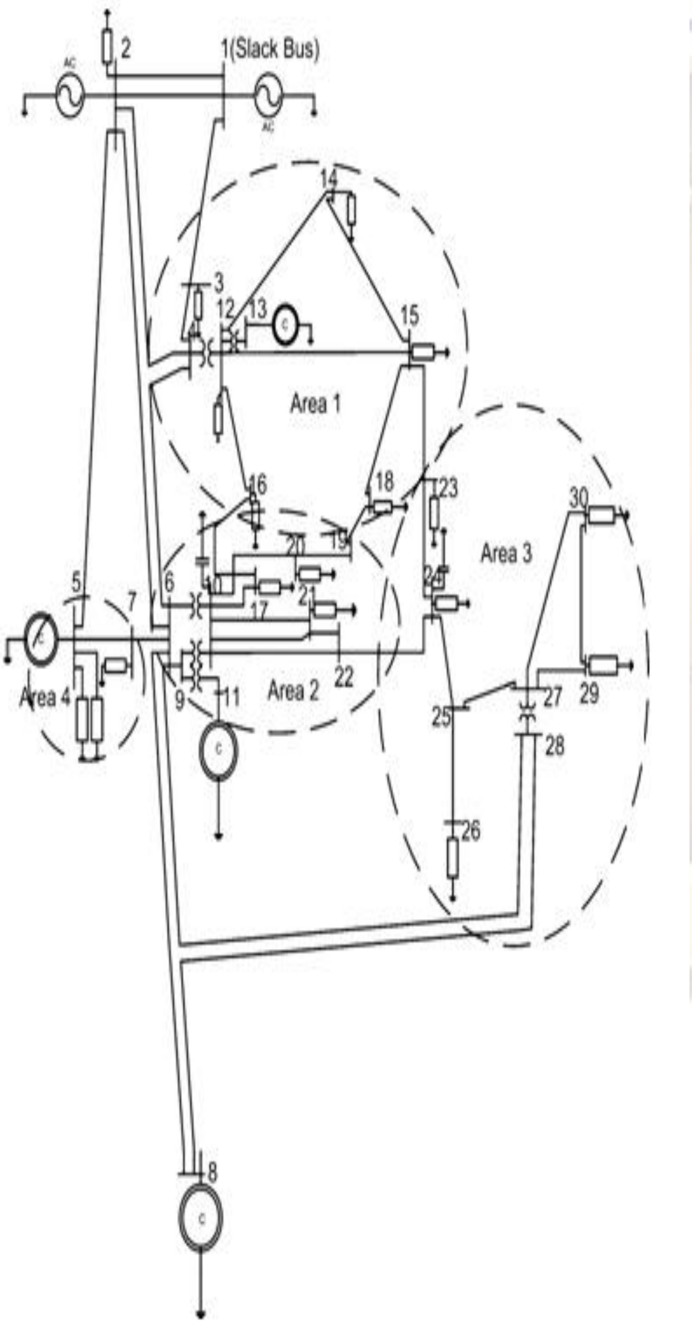

Fig. 9. IEEE benchmarked 30-bus system

Area	Buses	Total amount of power consumption in loads
Area 1	3,4,12,13,14,15,16,18	45 MW
Area 2	10,11,17,19,20,21,22	44 MW
Area 3	23,24,25,26,27,29,30	28.4 MW
Area 4	5,7	117 MW

Table-2

Busses used in each area in fig .9

Area	Largest load bus	Smallest load bus
Area 1	12	16
Area 2	10	22
Area 3	27	26
Area 4	5	7

Table-3

Busses with largest loads and smallest loads in each area in fig.9

When the unit circuit of Fig. 10 is considered, the power loss of each branch must be reduced to minimize the total power loss by connecting the DG to the load-concentration-bus as mentioned above. Fig. 10 shows the variation of power loss corresponding to the size of DG at load-concentration-bus 10 and the amount of load consumption at bus 21 in Fig.9. Here, it is clearly shown that the power loss is significantly reduced by increasing the size of DG connected to load-concentration-bus 10, which is very close to bus 21, when the power consumption of the load at bus21 is increased. All buses included in each area of the power system shown in Fig. 9 are presented in Table I with the total amount of power consumption. Table II gives the buses with the largest and smallest loads in each area. To minimize the total power loss, the largest load buses in each area, which are buses 12, 10, 27, and 5, can be selected as the optimal locations for the multiple DGs as the representative load-concentration-buses. Assume that the power losses between two adjacent buses in each area are negligible. In this case, the multiple DGs with the same size as the total amount of power consumption at each area might be implicitly used to minimize the power loss. In other words, the total system power loss is 3.452 MW if each DG in Areas 1 through 4 supplies the real power of 45, 44, 28.4, and117 MW, respectively. The resulting system power loss of 3.452MW will be compared with the total power loss computed after the optimal size of multiple DGs is systematically determined by using the Kalman filter algorithm, as described in next Section.

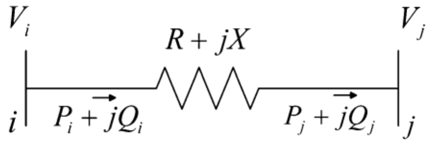

Fig.10.Simplified unit circuit between two buses.

From the simplified unit circuit shown in Fig.10, the power loss, P_{loss} between two buses i and j, is computed by the following:

$$P_{loss,ij} = P_i - P_j = \frac{(P_i^2 + Q_i^2)r}{V_i^2} \quad (5.1)$$

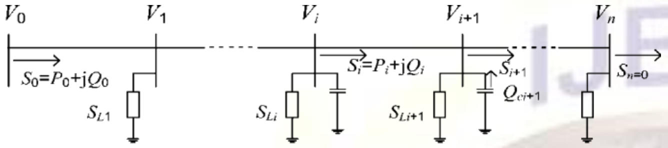

Fig.11. One-line diagram of a distribution feeder.

Also, the one-line diagram of a distribution feeder with a total of n unit circuits is shown in Fig. 11. When power flows in one direction, the value of bus voltage**,** Vi+1, is smaller than that of V_i, and this associated equation can be expressed by (5.2). In general, the reactive power, Q_i, is reduced by connecting a capacitor bank on bus Vi, in order to decrease the voltage gap between Vi+1 and V_i. In other words, the capacitor bank at bus makes it possible to reduce power loss and regulate the voltages by adjusting the value of Q_i in the following:

$$V_{i+1}^2 = V_i^2 - 2(r_{i+1}P_i + x_{i+1}Q_i) + (r_{i+1}^2 + x_{i+1}^2)(P_i^2 + Q_i^2)/V_i^2 \quad (5.2)$$

If a DG is installed at the location of the capacitor bank, the proper reactive power control of the DG has the same effect on the system as does the capacitor bank. Moreover, the main function of the DG is to supply real supplementary power to the required loads in an effective manner.

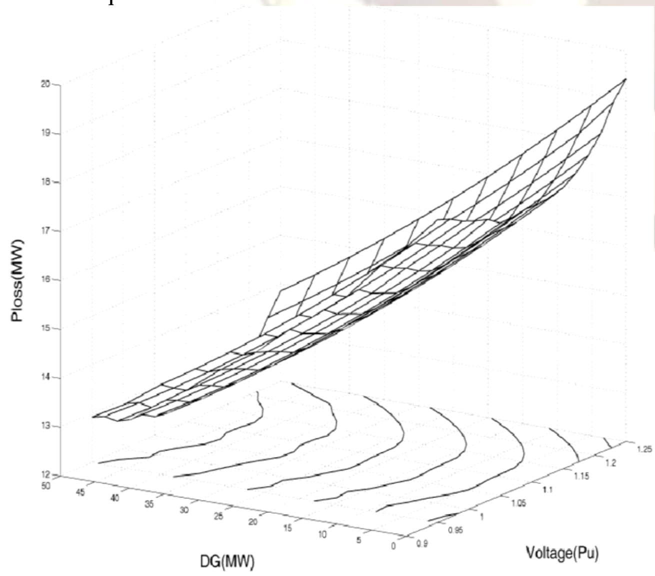

Fig.12. power loss corresponding to oltage and power of the DG.

Fig.12 shows the system power loss corresponding to the different power and voltage scales of the DG at the load-concentration-bus 10 in Area 2 of Fig.9. This DG supplies real power in the range of 0 to 40 MW. The voltage at bus 10 varies between 0.95 to 1.25 p.u. with the proper control for the DG. It is observed that the overall power loss is decreased almost linearly as the size of DG increases. In addition, it is minimized when the bus voltage is 1.06 p.u. with 40 MW of DG. The variation of power loss is relatively less sensitive to voltage changes when compared to the size of DG. In other words, the amount of real power supplied by the DG strongly influences the minimization of power loss. This means that the DG can control the bus voltage for reactive power compensation independently of its real power control to minimize power loss.

5.2. SELECTION OF OPTIMAL LOCATION FOR DG's CONSIDERING POWER LOSS:

Before deriving the equations necessary to select the optimal location for the DG, the following terms are firstly defined. In particular, the factor, D, shown in the following is called the generalized generation distribution factor

P_k: Power supplied by the kth generator in a power network;

P_l: Power consumed by the lth load in a power network;

$P_{k,l}$: Power flowing from the kth generator to the lth load;

$F_{jl,k}$: Power flowing from the kth generator to the lth load through bus j to the lth load;

$D_{jl,k}$ Ratio of $F_{jl,k}$ to the power supplied by the kth generator;

$P_{\text{loss, k}}$ Power loss on transmission line due to the power supplied from the k[th] generator

$F_{kj,l}$ Power flow from the kth generator to the lth load through bus j connected to the kth generator;

$D_{kj,l}$ Ratio of $F_{kj,l}$ to the power supplied by the kth generator;

$P_{\text{loss, k}}$ Power loss on a transmission line due to power supplied to the l[th] load

The IEEE benchmarked 30-bus system in Fig. 9 is now analyzed for two different cases with respect to generator or load In other words, the first case is one where power flows from the kth generator to numerous loads. The second case is one where power is flowing from several generators to the lth load. These two conditions are shown in Figs. 13 and 14, respectively.

Case 1 :-

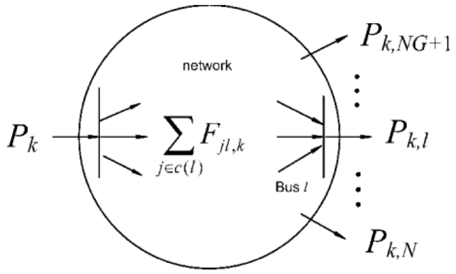

Fig.13. Power flow from the Kth generator to the other several loads.

Case 2 :-

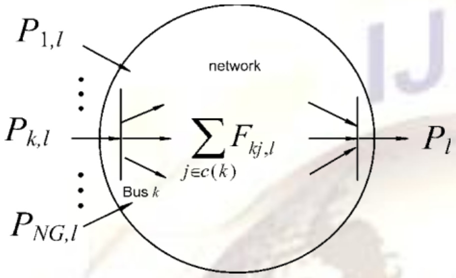

Fig-14 Power flow from the several generators to the Lth load.

Simplified form of two cases (1) & (2) :-

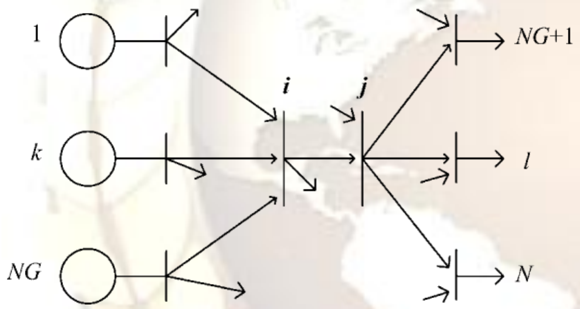

Fig-15 Simplified circuit with only power generations and consumptions. For the first case (case-1), the power supplied from the kth generator to the lth load among several loads is calculated by the following:

$$P_{k,l}/case-1 = \sum_{j \in c(l)} F_{jl,k} = \sum_{j \in c(l)} D_{jl,k} P_k \quad (5.3)$$

where $c(l)$ are the buses connected to the L th load. Then, the power loss associated with the K th generator is computed by the following, which is the difference between the power supplied from the kth generator and the sum of powers consumed in loads:

$$P_{loss,k} = P_k - \sum_{l=NG+1}^{N} P_{k,l} \quad (5.4)$$

In the same manner, the power supplied from the kth generator among several generators to the lth load is calculated by thefollowing for the second case (case-2):

$$P_{k,l}/case-2 = \sum_{j \in c(k)} F_{kj,l} = \sum_{j \in c(k)} D_{kj,l} P_l \quad (5.5)$$

where $c(k)$ are the buses connected to the K th generator.

The power loss associated with the lth load is computed by the following:

$$P_{loss,l} = \sum_{k=1}^{NG} P_{k,l} - P_{l.} \quad (5.6)$$

In a combination of the cases described above, the power system in Fig. 9 can be expressed by the simplified circuit shownin Fig.15 with consideration of only power generations and consumptions. The branch between buses i and j in Fig. 15 can become an arbitrary branch in Fig. 9. This means that the total power loss of the system can be calculated by summing the losses of all branches whenever the DG is connected to any bus.

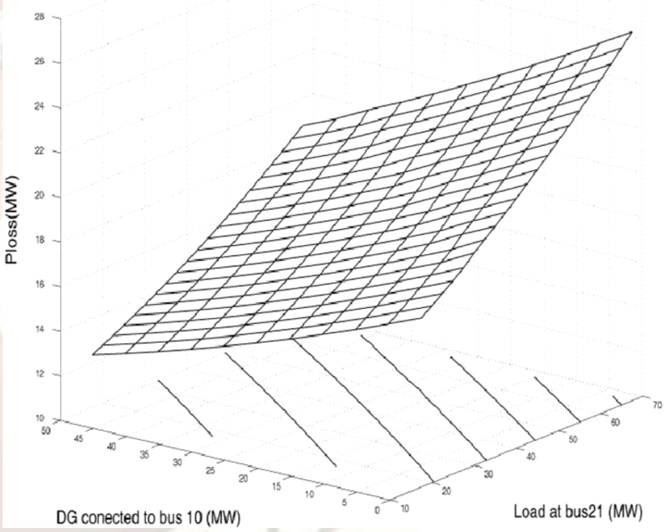

Fig-16 Variation of power loss corresponding to the size of DG at load -concentration-bus 10 and the amount of load consumption at bus 21.

5.3. PROCEDURE TO SELECT OPTIMAL SIZE OF MULTIPLE DG's USING KALMAN FILTER ALGORITHM:

The total amount of power consumption in Table I at each area could be choosen as the size of DGs to be placed. However, these are not optimal values for the DGs because the power loss in lines connecting two buses is ignored. To deal with this problem, the Kalman filter algorithm is applied to select the optimal sizes of multiple DGs by minimizing the total power loss of system. The Kalman filter algorithm has the smoothing properties and the noise rejection capability robust to the process and measurement noises. In practical environments (in which the states are driven by process noise and observation is made in the presence of measurement noise), the estimation problem for the optimal sizes of multiple DGs can be formulated with a linear time-varying state equation. Also, the error from interval of computation can be reduced during the estimation optimization process. In this study, the state model applied for the estimation is given as

$$x(n+1) = \phi x(n) + \Gamma\omega(n), x(0) = x_0$$

$$y(n) = c.x(n) \qquad (5.7)$$

$$z(n) = y(n) + v(n)$$

- where the matrices Φ, Γ, C are known deterministic variables,
- The state vector x can represent the size of each of the multiple DGs or their coefficients.
- ω is the process noise vector,
- Z is the measured power loss,
- Vis stationary measurement noise

Then, the estimate of the state vector is updated by using the following steps.

5.3.1. Measurement update:

Acquire the measurements, $z(n)$, and compute *a posteriori* quantities:

$$k(n) = P^{-}(n)c^{T}[cP^{-}(n)c^{T} + r]^{-1}$$

$$\hat{x}(n) = \hat{x}^{-}(n) + k(n)[z(n) - c\hat{x}^{-}(n)] \qquad (5.8)$$

$$P(n) = P^{-}(n) - k(n)cP^{-}(n)$$

Where K($\mathbf{R}^{n\times 1}$) is the Kalman gain,

- P is a positive definite symmetric matrix
- r is a positive number selected to avoid a singular matrix.

5.3.2. Time update:

$$\hat{x}^{-}(n+1) = \Phi\hat{x}(n)$$

$$P^{-}(n+1) = \Phi P(n)^{T} + \Gamma Q\Gamma^{T} \qquad (5.9)$$

where Q($\mathbf{R}^{m\times m}$) is a positive-definite covariance matrix, which is zero in this study because the stationary process and measurement noises are mutually independent.

5.3.3. Time increment: Increment n and repeat.

Thereafter, the estimated output (the total power loss of the system) is calculated as

$$\hat{y}(n) = C\hat{x}(n) \qquad (5.10)$$

C is known as deterministic variable

Fig. 11 shows the procedure to obtain data samples n for the sizes of multiple DGs and the power loss required before applying the Kalman filter algorithm. In Stage-1 of Fig. 11, the algorithm begins with the zero values for all DGs, and the *index* denotes the number of given DG. After adding the small amount of power P_{step} of 10 MW to each DG, the initial power loss is obtained by a power flow computation based on the Newton–Raphson method. Then, the information on the individual power loss, P_{loss}, corresponding to each DG increased by 10 MW is sent to Stage-2, where the values of P_{loss} are substituted with those of P_{temp}. After the minimum value of P_{temp} is selected, its value and the corresponding sizes of multiple DGs are stored in the memory of $P_{\text{losses},n}$ and DG$_{i,\text{samples}}$in Fig. 11, respectively. This process is then repeated until the total sum of all DGs is the same as the predefined value $P_{\max}$, in Stage-3 by increasing n to n+1. Finally, the accumulated data of the minimum power loss and sizes of DGs, which are $P_{\text{losses,samples}}$ and DG$_{i,\text{samples}}$, respectively, are obtained.

5.4. FLOWCHART FOR KALMAN FILTER ALGORITHM:

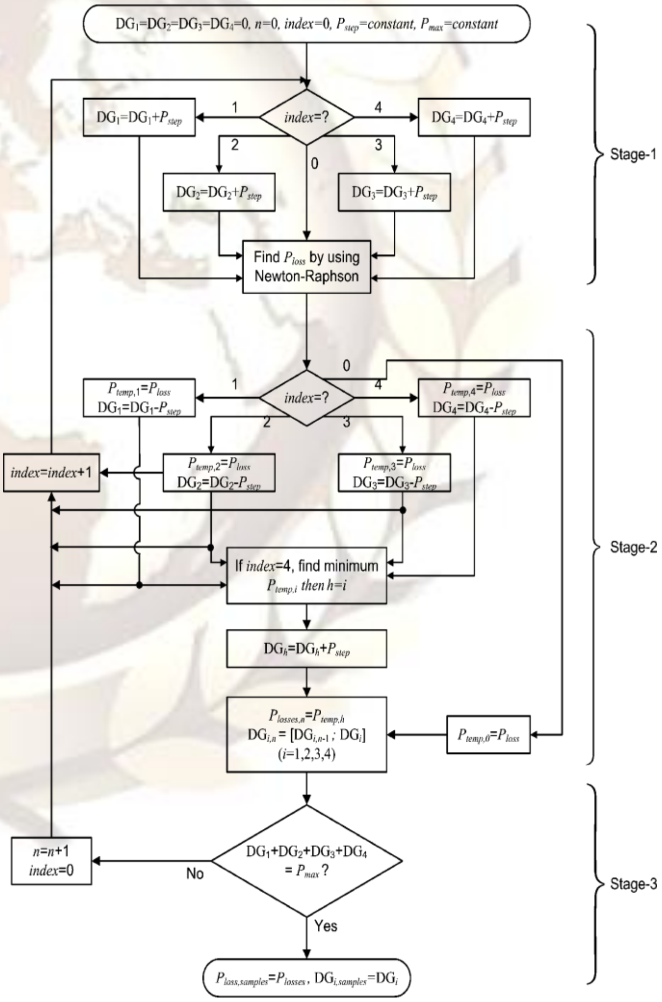

Fig-17 Procedure to obtain data samples of the multiple DGs and power loss required before applying the Kalman filter algorithm.

The data samples obtained above might be different from the actual values due to the large sampling interval of 10 MW. If this sampling interval is reduced to find more accurate values, the computational requirement will be dramatically increased. To deal with this problem in Fig. 10 with two phases in application of the Kalman filter algorithm are taken to reduce the error between the estimated and actual values, and then the optimal sizes of multiple DGs are finally estimated.

In Phase-1 of Fig. 12, the estimated sizes of multiple DGs, $DG_{i,\mathrm{estimated}}$,are determined by applying the Kalman filter algorithm with the data samples obtained from Fig. 11, which are $P_{\mathrm{losses,samples}}$ and . Its associated parameters are then given in the following:

$$\delta(n) = \sum_{i=1}^{4} DG_{i,samples}(n) / \max \times \{\sum_{i=1}^{4} DG_{i,samples}(n)\} \quad (5.11)$$

$$C_{phase-1}(n) = [\delta(n), \delta^2(n), \delta^3(n), \delta^4(n)] \quad (5.12)$$

$$z(n)/i = DG_{i,samples}(n) \quad (5.13)$$

$$DG_{i,estimated}(n) = \hat{y}(n) = C_{phase-1}(n) . \hat{x}_{Phase-1}(n_{max})/i \quad (5.14)$$

where δ is the normalized value, n_{max} is the number of last samples in $DG_{i,samples}$. To estimate the size of each DG, the Kalman filter algorithm is applied in sequence with different measurements of Z in (5.13).

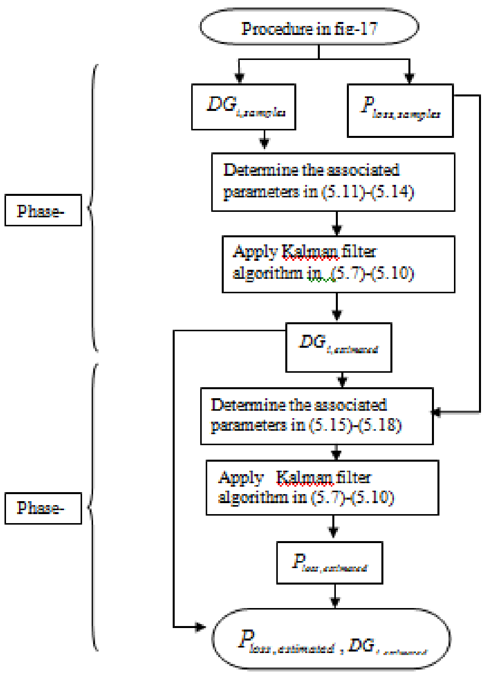

Fig-18 Steps to estimate the optimal size of multiple DGs in two phases by applying the Kalman filter algorithm.

After estimating the optimal sizes of multiple DGs in Phase-1, the total power loss, $P_{loss,estimated}$, is estimated in Phase-2 of Fig. 18 with the power loss data samples, $P_{loss,samples}$, from Fig. 17 and the estimated DG sizes, $DG_{i,estimated}$, in Phase-1. The associated parameters required to apply the Kalman filter algorithm are given in the following:

$$\beta_i(n) = DG_{i,estimated}(n), \quad (i = 1,2,3,4) \quad (5.15)$$

$$C_{phase-2}(n) = [\beta_1(n), \beta_2(n), \beta_3(n), \beta_4(n)] \quad (5.16)$$

$$Z(n) = P_{loss,samples}(n) \quad (5.17)$$

$$P_{loss,estimated}(n) = \hat{y}(n) = C_{phase-2}(n) . \hat{x}_{Phase-2}(n_{max}) \quad (5.18)$$

V. SIMULATION RESULTS

WITH OUT CONNECTING DG'S AND KALMAN FILTER

BUS DATA FOR IEEE 30-BUS SYSTEM

RESULTS FOR WITH OUT DG'S AND KALMAN FILTER

Newton Raphson Loadflow Analysis

Bus No.	V pu	Angle Degree	Injection MW	Injection MVar	Generation MW	Generation Mvar	Load MW	Load MVar
1	1.0600	0.0000	262.416	-128.472	262.416	-128.472	0.000	0.000
2	1.0930	-6.0245	18.300	138.377	40.000	151.077	21.700	12.700
3	1.0558	-7.7353	-2.400	-1.200	-0.000	0.000	2.400	1.200
4	1.0550	-9.4944	-7.600	-1.600	-0.000	0.000	7.600	1.600
5	1.0600	-14.0140	-94.200	16.315	-0.000	35.315	94.200	19.000
6	1.0597	-11.2035	0.000	0.000	0.000	0.000	0.000	0.000
7	1.0525	-12.8376	-22.800	-10.900	0.000	0.000	22.800	10.900
8	1.0600	-11.8910	-30.000	6.979	0.000	36.979	30.000	30.000
9	1.1005	-13.9711	0.000	0.000	0.000	0.000	0.000	0.000
10	1.0938	-15.4205	-5.800	17.000	0.000	19.000	5.800	2.000
11	1.1320	-13.9711	0.000	17.152	0.000	17.152	0.000	0.000
12	1.1070	-14.6820	-11.200	-7.500	0.000	0.000	11.200	7.500
13	1.1210	-14.6820	0.000	11.200	0.000	11.200	0.000	0.000
14	1.0930	-15.4893	-6.200	-1.600	0.000	-0.000	6.200	1.600
15	1.0888	-15.5703	-8.200	-2.500	0.000	-0.000	8.200	2.500
16	1.0945	-15.2423	-3.500	-1.800	0.000	0.000	3.500	1.800
17	1.0889	-15.5556	-9.000	-5.800	0.000	-0.000	9.000	5.800
18	1.0790	-16.1487	-3.200	-0.900	0.000	-0.000	3.200	0.900
19	1.0762	-16.3187	-9.500	-3.400	0.000	-0.000	9.500	3.400
20	1.0798	-16.1465	-2.200	-0.700	0.000	0.000	2.200	0.700

21	1.0800	-15.8843	-17.500	-11.200	0.000	-0.000	17.500	11.200
22	1.0858	-15.7298	0.000	0.000	0.000	0.000	0.000	0.000
23	1.0799	-15.8897	-3.200	-1.600	0.000	-0.000	3.200	1.600
24	1.0748	-16.0639	-8.700	-2.400	0.000	4.300	8.700	6.700
25	1.0716	-15.7192	0.000	0.000	0.000	0.000	0.000	0.000
26	1.0549	-16.0968	-3.500	-2.300	0.000	-0.000	3.500	2.300
27	1.0778	-15.2712	0.000	0.000	0.000	0.000	0.000	0.000
28	1.0595	-11.8142	0.000	0.000	0.000	0.000	0.000	0.000
29	1.0591	-16.3776	-2.400	-0.900	0.000	-0.000	2.400	0.900
30	1.0482	-17.1692	-10.600	-1.900	0.000	-0.000	10.600	1.900
Total			19.016	20.351	302.416	146.551	283.400	126.200

Line FLow and Losses

From Bus	To Bus	P MW	Q MVar	From Bus	To Bus	P MW	Q MVar	power Loss MW	power Loss MVar
1	2	175.327	-108.251	2	1	-168.072	129.978	7.255	21.728
1	3	87.088	-14.963	3	1	-83.947	26.443	3.141	11.480
2	4	43.713	10.764	4	2	-42.746	-7.817	0.967	2.947
3	4	81.547	-24.901	4	3	-80.686	27.373	0.861	2.472
2	5	82.227	4.288	5	2	-79.548	6.965	2.679	11.254
2	6	60.432	3.429	6	2	-58.650	1.978	1.782	5.407
4	6	71.573	-31.197	6	4	-70.921	33.464	0.652	2.267
5	7	-14.652	12.844	7	5	14.807	-12.452	0.155	0.392
6	7	37.951	-2.567	7	6	-37.607	3.624	0.344	1.057
6	8	29.499	-9.064	8	6	-29.397	9.421	0.102	0.356
6	9	27.680	-20.591	9	6	-27.680	22.747	-0.000	2.156
6	10	15.820	-6.133	10	6	-15.820	7.514	0.000	1.381
9	11	-0.000	-16.674	11	9	0.000	17.152	0.000	0.478
9	10	27.680	7.024	10	9	-27.680	-6.284	0.000	0.741
4	12	44.260	-20.980	12	4	-44.260	26.123	0.000	5.143
12	13	0.000	-11.060	13	12	-0.000	11.200	0.000	0.140
12	14	7.797	2.361	14	12	-7.731	-2.222	0.067	0.139
12	15	17.691	6.622	15	12	-17.498	-6.243	0.193	0.380
12	16	7.571	3.381	16	12	-7.518	-3.270	0.053	0.111
14	15	1.531	0.622	15	14	-1.526	-0.617	0.005	0.005
16	17	4.018	1.470	17	16	-4.006	-1.440	0.013	0.029
15	18	6.316	1.808	18	15	-6.277	-1.728	0.039	0.080
18	19	3.077	0.828	19	18	-3.071	-0.817	0.006	0.011
19	20	-6.429	-2.583	20	19	6.443	2.611	0.014	0.028
10	20	8.712	3.465	20	10	-8.643	-3.311	0.069	0.154
10	17	5.006	4.391	17	10	-4.994	-4.360	0.012	0.031
10	21	18.218	11.732	21	10	-18.081	-11.438	0.137	0.294
10	22	5.764	3.067	22	10	-5.738	-3.013	0.026	0.053
21	23	0.581	0.238	23	21	-0.581	-0.238	0.000	0.000
15	23	4.508	2.552	23	15	-4.486	-2.506	0.023	0.046
22	24	5.738	3.013	24	22	-5.697	-2.950	0.041	0.064
23	24	1.867	1.144	24	23	-1.861	-1.133	0.005	0.011
24	25	-1.142	1.683	25	24	1.148	-1.671	0.007	0.012
25	26	3.540	2.360	26	25	-3.500	-2.300	0.040	0.060
25	27	-4.688	-0.689	27	25	4.710	0.730	0.021	0.041
28	27	17.962	-4.519	27	28	-17.962	5.691	0.000	1.172
27	29	6.177	1.644	29	27	-6.100	-1.498	0.077	0.146
27	30	7.076	1.632	30	27	-6.930	-1.359	0.145	0.274
29	30	3.700	0.598	30	29	-3.670	-0.541	0.030	0.057
8	28	-0.603	0.468	28	8	0.604	-0.467	0.000	0.001
6	28	18.622	-4.807	28	6	-18.566	5.005	0.056	0.197
Total Loss								19.016	72.791

WITH CONNECTING DG'S AND KALMAN FILTER

BUS DATA FOR IEE 30-BUS SYSTEM

RESULTS FOR WITH DG AND KALMAN FILTER

OPTIMAL SIZES

DG= 47.2000 67.7000 27.7000 91.8000 Through Area-1 to Area-4

Newton Raphson Loadflow Analysis

Bus No.	V pu	Angle Degree	Injection MW	Injection MVar	Generation MW	Generation Mvar	Load MW	Load MVar
1	1.0600	0.0000	-0.344	-49.902	-0.344	-49.902	0.000	0.000
2	1.0830	-0.3378	18.300	48.700	40.000	61.400	21.700	12.700
3	1.0639	-0.2192	-2.400	-1.200	-0.000	0.000	2.400	1.200
4	1.0645	-0.2169	-7.600	-1.600	-0.000	0.000	7.600	1.600
5	1.0874	-1.2944	-2.400	18.000	91.800	37.000	94.200	19.000
6	1.0646	-0.4839	0.000	0.000	0.000	0.000	0.000	0.000
7	1.0665	-1.2744	-22.800	-10.900	0.000	0.000	22.800	10.900
8	1.0500	-0.8135	-30.000	-38.396	0.000	-8.396	30.000	30.000
9	1.1015	0.8115	0.000	0.000	0.000	0.000	0.000	0.000
10	1.0977	1.4908	61.900	17.000	67.700	19.000	5.800	2.000
11	1.1220	0.8115	0.000	11.068	0.000	11.068	0.000	0.000
12	1.1105	1.8414	47.200	0.000	47.200	0.000	0.000	0.000
13	1.1110	1.8414	0.000	0.386	0.000	0.386	0.000	0.000
14	1.0964	1.1033	-6.200	-1.600	0.000	-0.000	6.200	1.600
15	1.0926	1.0887	-8.200	-2.500	0.000	-0.000	8.200	2.500
16	1.0983	1.4452	-3.500	-1.800	0.000	-0.000	3.500	1.800
17	1.0928	1.2895	-9.000	-5.800	0.000	-0.000	9.000	5.800
18	1.0829	0.6032	-3.200	-0.900	0.000	-0.000	3.200	0.900
19	1.0801	0.4877	-9.500	-3.400	0.000	-0.000	9.500	3.400
20	1.0837	0.6868	-2.200	-0.700	0.000	-0.000	2.200	0.700
21	1.0840	0.9710	-17.500	-11.200	0.000	-0.000	17.500	11.200
22	1.0899	1.1572	-0.000	-0.000	-0.000	-0.000	0.000	0.000
23	1.0839	0.9464	-3.200	-1.600	-0.000	-0.000	3.200	1.600
24	1.0791	0.7897	-8.700	-2.400	0.000	4.300	8.700	6.700
25	1.0769	1.0866	0.000	0.000	0.000	0.000	0.000	0.000
26	1.0602	0.7128	-3.500	-2.300	0.000	-0.000	3.500	2.300
27	1.0835	1.5034	27.700	0.000	27.700	0.000	0.000	0.000
28	1.0648	-0.3677	0.000	0.000	0.000	0.000	0.000	0.000
29	1.0649	0.4090	-2.400	-0.900	0.000	0.000	2.400	0.900
30	1.0541	-0.3739	-10.600	-1.900	0.000	-0.000	10.600	1.900
Total			1.856	-43.845	274.056	74.855	272.200	118.700

Line FLow and Losses

From Bus	To Bus	P MW	Q MVar	From Bus	To Bus	P MW	Q MVar	power Loss MW	power Loss MVar
1	2	-2.137	-41.652	2	1	2.434	42.542	0.297	0.890
1	3	1.793	-2.992	3	1	-1.788	3.010	0.005	0.018
2	4	2.155	10.835	4	2	-2.096	-10.654	0.059	0.181
3	4	-0.612	-1.425	4	3	0.613	1.426	0.000	0.001
2	5	8.855	-4.453	5	2	-8.816	4.619	0.040	0.166
2	6	4.855	9.675	6	2	-4.797	-9.498	0.058	0.176
4	6	11.679	-3.738	6	4	-11.663	3.793	0.016	0.055
5	7	6.416	17.059	7	5	-6.287	-16.733	0.129	0.326
6	7	16.592	-7.718	7	6	-16.513	7.960	0.079	0.242
6	8	23.976	30.329	8	6	-23.818	-29.775	0.158	0.554
6	9	-13.032	-19.130	9	6	13.032	20.091	0.000	0.962
6	10	-7.474	-6.396	10	6	7.474	6.856	0.000	0.460
9	11	-0.000	-10.865	11	9	0.000	11.068	-0.000	0.202
9	10	-13.032	3.895	10	9	13.032	-3.727	0.000	0.168
4	12	-17.795	-20.214	12	4	17.795	21.741	0.000	1.527
12	13	0.000	-0.385	13	12	-0.000	0.386	0.000	0.000
12	14	7.380	2.600	14	12	-7.319	-2.473	0.061	0.127
12	15	15.914	7.269	15	12	-15.750	-6.946	0.164	0.324
12	16	6.110	3.922	16	12	-6.070	-3.837	0.040	0.085
14	15	1.119	0.873	15	14	-1.116	-0.870	0.004	0.003
16	17	2.570	2.037	17	16	-2.562	-2.020	0.007	0.017
15	18	5.627	2.118	18	15	-5.595	-2.051	0.032	0.066
18	19	2.395	1.151	19	18	-2.391	-1.144	0.004	0.008
19	20	-7.109	-2.256	20	19	7.125	2.289	0.016	0.032
10	20	9.402	3.159	20	10	-9.325	-2.989	0.076	0.171
10	17	6.453	3.819	17	10	-6.438	-3.780	0.015	0.039

10	21	19.538	11.031	21 10	-19.393	-10.718	0.145	0.313	
10	22	6.001	2.794	22 10	-5.975	-2.740	0.026	0.055	
21	23	1.893	-0.482	23 21	-1.892	0.483	0.000	0.001	
15	23	3.038	3.198	23 15	-3.022	-3.165	0.016	0.033	
22	24	5.975	2.740	24 22	-5.933	-2.675	0.042	0.065	
23	24	1.714	1.082	24 23	-1.710	-1.073	0.005	0.009	
24	25	-1.057	1.348	25 24	1.062	-1.339	0.005	0.008	
25	26	3.540	2.359	26 25	-3.500	-2.300	0.040	0.059	
25	27	-4.602	-1.020	27 25	4.623	1.060	0.021	0.040	
28	27	-9.827	-5.057	27 28	9.827	5.470	0.000	0.413	
27	29	6.176	1.642	29 27	-6.099	-1.497	0.076	0.144	
27	30	7.074	1.630	30 27	-6.930	-1.359	0.144	0.271	
29	30	3.699	0.597	30 29	-3.670	-0.541	0.030	0.056	
8	28	-6.182	-5.765	28 8	6.223	5.895	0.041	0.130	
6	28	-3.602	0.827	28 6	3.604	-0.820	0.002	0.007	
Total Loss							1.856	8.405	

COMPARISION OF TOTAL POWER LOSS FOR OOPTIMAL AND INITIAL SIZES OF MULTIPLE DG's

	DG 1	DG 2	DG 3	DG 4	SUM OF DG's	TOTAL Ploss
OPTIMAL	47.2 MW	67.7 MW	27.7 MW	91.8 MW	234.4 MW	2.186 MW
INITIAL	45 MW	44MW	28.4MW	117 MW	234.4 MW	19.016 MW

VI. CONCLUSION

This Project determine a method for selecting the optimal locations and sizes of multiple distributed generations (DGs) to minimize the total power loss of system. To deal with this optimization problem, the Kalman filter algorithm was applied. When the optimal sizes of multiple DGs are selected, the computation efforts might be significantly increased with many data samples from a large-scale power system because the entire system must be analyzed for each data sample. The proposed procedure based on the Kalman filter algorithm took the only few samples, and therefore reduced the computational requirement dramatically during the optimization process.

Prior to the implementation and connection to an electric power grid, this study can be used as a decision-making process in the power system operation and planning for selecting the optimal locations and sizes of multiple DGs based on the renew- able energy resources such as fuel cell, photovoltaic, micro-turbines, wind powers, etc..

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