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Optimal Operating Strategies for the Integration of Distributed Power Generation with Microgrid-A Review

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ABSTRACT: The energy demand is sharply increasing due to industrialization, huge population growth, and increased comfort lives etc. This energy demand mostly extracts from the fossil fuels which is non-renewable and the known reservoirs expected to finish in near future. The whole world may face energy crisis soon, altogether the fossil fuel produces greenhouse gasses (GHG) which cause the climate change. This is detrimental for the countries whose economy mostly leans on the per capita consumption of energy. That's why it is highly required to exploit the renewable energy sources (RES) and generate power at its maximum limit to strive with a faster increase in demand for electrical energy. Moreover, the worldly scenario of economical and constitutional conditions suggest that developing countries like India which has a vast resource of renewable energy must develop its renewable energy resources technologies. The renewable energy resources include solar photovoltaic, geothermal, tidal, wind energy, hydroelectricity, fuel cell and biomass, these resources have vast scope for power generation in India. Out of these energy resources, solar photovoltaic technology is very useful especially for remote areas, where it is expensive to have grid lines. In this paper, optimal operating strategies of solar photovoltaic (SPV) generation is discussed. This composition is essentially divided into the following three main categories namely: effective energy storage systems, system design, and methods to adjust active and reactive power for mitigating the voltage rise issue, the techno-economic practicability of solar photovoltaic power generation.

KEYWORDS: climate change; energy storage system; fossil fuel; renewable energy resource; system design methods; techno-economic practicability

I. INTRODUCTION

The power generation by SPV and the wind because of its renewable feature and environmental benefits, coming into the picture at a fast pace. The renewable energy resources major advantage is pollutant free. It does not emit greenhouse gasses like carbon dioxide, Nitrogen Oxides (NOx) etc which causes climate change. As the whole world is facing the problem of unexpected climate change, like drought, heavy rain, glacier melting and different types of infections etc. The renewable energy sources are the best alternative to power generation to meet the sharp increase in energy demand. The pollutants which are coming out from conventional power plants are very detrimental for the human being. The whole ecological system is getting disturbed due to pollutants. This is an alarming situation for the countries especially those whose total development leans on the electrical energy consumption. SPV ranges from rooftop distributed power generation (kW) to the Megawatts are coming with a fast pace and is expected to meet Jawaharlal Nehru National Solar Mission (JNNSM) of 20,000 MW by 2022. JNNSM also aims to achieve grid parity tariff by 2022 through Research and Development in the semiconductor material, by local manufacturing of solar panels, large-scale utilization and fast deployments of solar technologies. Due to rapid advancement in technology, it became easier to use especially solar and wind energy which is highly intermittent to occur in nature. The existing electricity grids are going to be converted into the future smart grid with the help of microgrids. The microgrids are helpful to make the power more reliable and less reliance on carbon emitting plants which uses fossil fuels to generate electricity. Section 2 deals with the effective energy storage system that energy system should be charged and

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discharged according to the variation of load. Section 3 deals with different control methods namely unity power factor control and constant voltage control. Usually, the unity power factor control operates, but when the bus voltage violates the constraint, the constant voltage control starts. Section 4 explains different control strategies used to control the bus voltage and it explains that on-load tap changing transformer (OLTC) shows more benefit as compared to other control strategies.

II. EFFECTIVE ENERGY STORAGE SYSTEM

The SPV integration to grid through effective energy storage system (EESS) sharply increases the reliability of the grid and provides the easier monitoring of the grid. The features of SPV can be optimized through monitoring the rate of charging and discharging of energy storage system to control the variation of real power while integrating with the smart grid.

By using the droop control method for regulation of varying reactive power and frequency, the threat of SPV integration can economize [1], this has been verified by applying the method to the UK energy system forecasted for 2030. The mathematical representation is based on mixed integer linear programming (MILP) method with hourly time resolution and time horizon of one year. Different types of constraints have been taken viz: power balance constraint, generation operating constraint, storage operating constraint, Demand- side response (DSR) constraint, operating reserve constraint, power flow constraints and distribution network peak load constraints. This case study shows that the inclusion of energy storage system offers an advantage in a different section of power system network e.g. generation, transmission, and distribution. Besides, the use of energy storage offers power demand and supply balance, supplies to the nearby loads which makes the line free from heavy current and it reduces the need for further expenditure to enhance the current carrying capability of the line [2].The use of energy storage system (ESS) for microgrid (MG) could increase the benefit of the microgrid and decreases the annual unit commitment scheduling cost in islanded system. Total saved revenue increases or the cost of scheduling of different power plants connected with the microgrid decreases with the increase of the size of ESS. Although, the scheduling expense of the plants leans on the size of ESS. With the greater optimum capacity of ESS, the overall benefit in grid-connected microgrid reduces and the total cost in islanded microgrid increases. Therefore, the optimal capacity of ESS differs in both cases. The decrement of total unit commitment scheduling cost in islanded mode has two components, the first component shows that the battery ESS can store the surplus energy generated by renewable sources and supply the stored energy during high demand of power or low generation. This could flatten the power supplied by the intermittent distributed power generation which could make the generator to operate at a stable condition and reduces the expenditure occur by alleviating the closedown and association frequency. Secondly, the energy accumulated in battery energy storage system (BESS) can be considered as a mode of the reservoir to assist the microgrid in meeting the inventory constraints which reduces the capital cost of the microgrid. These two integrals also enhance the maximum benefit in the grid-connected microgrid. Altogether, the BESS stores energy during high generation and low demand and supply the stored energy during low generation and high demand. Again this helps in increasing the maximum benefit. The results of grid-connected and the islanded mode microgrid show that BESS with optimum capacity could enhance total benefit for the grid tied MG and lessen the total cost for the islanded MG. When contrasting with the grid-tied MG without BESS, the installation of 400 kWh BESS increases the total benefit by 2% per day. When the optimal capacity of 400 kWh BESS will install with islanded system reduces the total cost by 8.64% as compared to islanded system without BESS. The optimal solution also minimizes the frequency of charging and discharging which increases the life of batteries [3].The voltage structure of residential distribution system has been upgraded by using rooftop solar photovoltaic and BESS. The mega integration of rooftop solar photovoltaic causes voltage rise, this problem has been mitigated by grid reinforcement approach based on the effective cooperation of society members. To control the voltage rise, the feeder with high resistance requires the reactive capacity of PV inverter and droop based regulation of BESS altogether [4].The feed-in tariff has lessened as compared to electricity price for that household which causes the more use of BESS which in turn increases the consumption of locally generated PV power. The grid which is highly PV power penetrated does not get benefit by increased local consumption. Different voltage control strategies using inverter and battery have been studied and found that the blend of voltage-dependent battery charging, active power curtailment, and automatic reactive power provision provides a voltage regulation capacity to the self-consumption blueprints [5]. The microgrid which employs RES such as SPV and the wind, to operate the microgrid optimally,

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rolling horizon controller based on MILP has been adopted. The performance objective of the controller fulfills by the use of predicted energy demand. The performance objective of the controller includes the cost of electricity usage, cost of battery operation, peak demand and load smoothing. The ambiguity in the forecast of power demand and renewable energy generation can be handled by a limited increase in the computation of the controller [6].The combination of battery energy storage (BES) and photovoltaic (PV) enables the line to flow more power and the voltage stability increased. To seize the power factor and size of the combination of PV and BESS, a novel mathematical formula has been proposed based on a multi-objective index (IMO). To conclude the optimal capacity of several PVs and BES unit while considering the variable load demand and intermittency of renewable energy sources an algorithm of self-correction feature has been proposed . This novel mathematical expression and self-correction algorithm have been applied for 33-bus profit making distribution system and the result shows the effectiveness of the prospective methodology. The energy loss and voltage stability improve by this methodology as compared to that with the unity power factor which is recently followed by IEEE 1547 [7].When the SPV generation is higher than the power requirement and this excess power fed to the distribution system, the voltage rises. The energy storage system of distributed nature is proposed to control the voltage rise problem. An intelligent strategy for the charging and discharge of battery has been proposed for the effective use of battery capacity [8].The grid limitation which leads to more active power curtailment and the power loss are not compensated financially, the battery energy storage system proved as a more attractive option. The grid up gradation reduces the revenue which could be a danger to the investors. The simulation outcomes also present that the optimum composition can be reliant on the position of the grid and the way of repository application: PV timeshift only, PV timeshift and arbitrage, PV self-consumption. Time shift and arbitrage would each lead to a different capacity of PV in terms of hours of discharge at full power and storage [9].

A prognostic control system based on a Dynamic Programming approach determines the optimal power flow to the grid coupled with BESS. The objective was to perform peak load shifting so that the owner of the system get benefited. The prime feature of this advent is aging of the battery which is supplying the whole day power. The real-time operation in simulated real conditions has been performed and outcomes contrasted with a simple ruled based management. The simulation for 24 hours, prognostic optimization gives around 13% of saving on the electricity payment. The exertion of the prognostic optimization algorithm into a microcontroller to conduct real-time management gives the technical potentiality of the approach suggested. Operation management in real conditions has verified the results and considerations from simulations. The management performances in real conditions heavily depend on the accuracy of the prediction and of the mode of operation. [10].The voltage rise issue of low voltage distribution system caused by high photovoltaic penetration is solved by correlated control of disseminated battery energy storage system with OLTC and voltage controllers of particular step size. Coordinated control relaxes the stress of tap changing transformer, shaves the peak load of the distribution network and decreases the power losses in distribution and transmission network. The coordinated control method limits the BESS depth of discharge so that the battery life cycle increases more than ten years. The real-time simulator has been utilized to evolve a distribution network model and the outcomes obtained from the case study verifies the proposed coordinated control methodology [11].An optimization model has been evolved to contrast the appearance of rooftop solar photovoltaic against high penetration of solar and wind farms installation in the planning of renewable energy sources. The objective of this model is to diminish the cost of annual generation and minimizing the emission of annual greenhouse gasses. More than twenty schemes were evolved to explore important input parameters such as highest level of infiltration of rooftop solar photovoltaic, equipment billing, tax credits, and net metering code to ascertain the appearance of rooftop solar PV scope in the investment of renewable energy. At a lower level of penetration, other renewable energy sources are the feasible option; the rooftop solar photovoltaic option should consider only when the development of renewable energy source is in increasing order. Cost minimization and the minimization of emission are two opposing objectives, by taking into account these opposing objectives, the balanced approach leads to a greater level of rooftop solar photovoltaic generation [12].

It has been concluded that the integration of SPV with MG through EESS becomes reliable and easier. The inclusion of energy storage system offers an advantage in a different section of power system network e.g. generation, transmission, and distribution. Besides, the use of energy storage offers power demand and supply balance, supplies to the nearby loads which make the line free from heavy current and it reduces the need for further expenditure to enhance the current carrying capability of the line

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III. SYSTEM DESIGN AND METHOD

Low voltage Solar PV is mostly connected to the distribution side of the transformer which has high resistance. Therefore, it is difficult to reduce the voltage at the bus due to local PV generation by varying power factor. Smart grid solutions may be a significant role in mitigating voltage rise issues and helps in keeping electric grid reliable and stable. A consolidation of supportive charter, enticement, technology evolution and costs decline have aided the coming up of photovoltaic distributed generation (PV-DG) plants of varying sizes from kW to multi-MW capacity. The integration of variable sources such as PV-DG may enhance voltage magnitude along distribution feeder which leads to further tap changer operations and line voltage controllers. The steady state voltage increases and the transitory voltage may increase beyond the limit prescribed by the distribution utilities under medium and high PV infiltration schemes. The simulation result shows that the inverter with generator emulator control capability is very compelling in alleviating the voltage rise problem and reduces the number of tap changer settings. The current DG interconnection standard IEEE 1547 does not allow the voltage control at DG location. Many standard working groups are centered on adapting the classics to entertain active cooperation of DG units in voltage control at DG location and reduction of possible blow on power system operation [13]. It is clear that the demand for photovoltaic power and other distributed energy system in particular areas remain a shock on the performance of a grid. During the period of high PV output, the amalgamated volt-VAR control benefits small system by lessen the voltage level at their meter. For the system of large order, the entire capacity of steady state and dynamic VAR control, ramp rate control, voltage supervising and output power abbreviation, low voltage ride through, utility communication, and other traits will be helpful in guaranteeing a decisive grid both at the dissemination and transportation stage [14].The economic analysis of different approaches used for polishing the yield power of giant PV system has been performed. The result shows that whatever the method used for flowing the yield power of PV system, there is revenue loss as compared to case which is without the smoothing system. For long-term economic aspect, the expensive sodium sulphide (NaS) battery energy storage proved to be exceptional to the inexpensive lead-acid (LA) batteries; this is due to the longer life and higher efficiency of NaS battery. The power rating of battery does not affected by increasing the period of operation of the battery in morning and evening. However, it has found that, the deficit in credit enhances with decrease of power fluctuation constraint. This is due to fact that by decreasing the power fluctuation limits, the power and energy rating of the battery increases. Bypass the exuberant power to meet the power fluctuation restraint and power abbreviation by operating below maximum power point prove to outcome in lower dividend deficit. Combining power abbreviation and battery energy storage system is found to be the highest efficient explication [15]. Low voltage Solar PV is mostly connected to the distribution side of the transformer which has high resistance. Therefore, it is difficult to reduce the voltage at the bus due to local PV generation by varying power factor. A combination of two control methods has been proposed namely unity power factor control and constant voltage control. Usually the unity power factor control operates, but if the voltage exceeds an operating range, the constant voltage control starts [16]. Droop based active power curtailment method for overvoltage avoidance in low voltage feeder with high infiltration of PV power has been discussed. In the basic active power curtailment method all inverters/houses use the same droop characteristics but the offering from all inverters/houses in terms of active power curtailment is distinct. Inverters ensuing on the feeder were deserved to trim more power than the others, which in turn affect their dividend. An avenue that results in commensurate apportionment of the yield power loss among all inverters was scheduled. This scheme gives more output power loss as compared to basic active power curtailment scheme [17]. A straightforward flexible breakthrough for the control of reactive power in a single line outspread dissemination system with large generation of photovoltaic power has been proposed. This algorithm designed to balance the voltage adjustment with the aim to play down the power deficit. The command signals are resolved based on local instantaneous value of the real and reactive power at each node. The importance of each of these performance matrices in the control design can be adjusted by the introduction of control parameter. By using the control parameter, the author has displayed that the flexible breakthrough can simultaneously exceed a local controller in both loss minimization and the voltage regulation [18].The impact of bunched rooftop solar photovoltaic in the forthcoming dissemination network can be assessed by the proposed advanced analytical tool. Actual moment system statistics collected from the auditing system or smart meters is huge; the proposed method will be apt to judge brilliantly which chunk of data would be efficient in analyzing the impacts of solar PV on distribution networks. Data mining techniques applied by the proposed tool to diagnose the secluded template and deviations in the clipped time series index. While applying the template exploration breakthrough and to reduce the computational effort, the

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suggested engine uses the symbolic aggregate approximation (SAX) illustration to diminish the ambit of the index [19].To alleviate the voltage rise of a distribution network, a simple distributed reactive power command accession has been proposed . The idea of this approach is not to command the bus voltage but to insured that the active power generation alone does not increase the nodal voltage [20]. Different conditions have been investigated namely standard condition, reducing the installed PV capacity, dangle based active power abbreviation (APA) design, dangle-based active power abbreviation designed for output power loss (OPL) sharing for voltage control during the high PV generation and low load. The houses which are located far from transformer is appropriated to abbreviate more power which affects their dividend. This problem can be removed by using APA-OPLS technique that contributes the yield power losses among all inverters. The energy required to curtail from downstream and upstream houses is nearly same [21-22].By the introduction of single-phase PV generators on low voltage distribution network, the voltage portrait and voltage disequilibrium along the feeder improves significantly without the use of additional voltage regulators. Consequently, it reduces the capital and maintenance cost. Active and reactive power generation control is required by robust control system [23]. Primary and secondary distribution network has been modeled using unbalanced load flow analysis with one minute resolution of load and generation data. This model shows that with 50% PV, the secondary distribution network voltage increases by 2V only, out of 230V. This level of PV penetration reduces the network losses and transformer loadings [24].The techno-economical analysis of grid-tied solar photovoltaic system has been analyzed by reinforcing the grid by a new transformer or by introducing a new line, by limiting the power feed- into the line not more than 70% of installed module capacity, static reactive power provision, automatic voltage constraint by changing active power control, automatic voltage constraint by mixed dynamic active/reactive power control, distribution transformer with OLTC. A 12-month rms simulation with a step-size of 1 min has been used to get the result. The active power curtailment strategy leads to the maximum annual total cost and this command blueprint diminishes the demand of further grid reinforcement cost. This strategy increases the cost of curtailed power share by the PV power plants [25].The voltage stability index (VSI) has been calculated and found that, in radial distribution system the bus having least VSI (most probable of voltage collapse) is more suitable for PV-DG placement. A test network has been taken and tested for three different cases e.g. single PV-DG system, multiple PV-DG system without back harmonics (BH) and with back harmonics and it has found that the , Placement of single PV-DG on a particular bus reduces the average system loss as compared to without PV-DG system. With the increment of BH, the total harmonic distortion in voltage (THDv) at node bus increases [26].With the interconnection of distributed power generation, the characteristics of the distribution line alters. The interconnection is not permitted if the basic constraints do not meet. Thermal rating, capacity of transformer, voltage portrait and the magnitude of short circuit current are envisaged as constraint [27]. A new formulation has been proposed for the optimum placement of DG so that the power loss would be minimum and the voltage sag gets reduced. This formulation has been solved by genetic algorithm and it found that the placement of DGs to the centre of the load, the line loss reduces. The author has used medium voltage power distribution network for case study. Thermal rating, transformer capacity, voltage profile and short-circuit level are taken into account as technical constraint. From this proposed methodology, it found that when the DG generation is higher, the best allocation of the DG, the prospective buses, should not be predetermined; if the buses or the rating of DG penetration is predetermined then the maximum DG penetration is restricted. On all the buses the technical constraints are required to check that which is responsible for optimum DG infiltration. The proposed methodology offers fair outcomes for small distribution system. This method is time consuming and more effort required to calculate all the technical constraints on all the network buses for optimum DG penetration. This method uses many simplifications which may lead to dubious results. With the help of NEPLAN software the calculation of power flow and short circuit analysis can be conducted by user-written programs [28-29].In this paper it has been found that the faced installation and roof top installation both together gives more power generation. In exterior installation, the solar radiation falling on the cells depend on the direction of facing and the degree of inclination. In the north hemisphere of the earth ,PV array facing southeast and southwest receives more radiation as compared to facing with northeast and north-west and vice versa. It has been found that the horizontal inclination of 60^0 and vertical inclination of 15^0 receives optimum solar insulation. It has found that for rooftop installation, the thin film amorphous silicon gives high output energy due to its intrinsic characteristics when installed in curved fashion [32].In metropolitan cities, there is good coincidence between solar power generation and the power demand. In Brazilian metropolitan the maximum power demand is due to air conditioning load when there is maximum solar power available. The Effective load carrying capacity (ELCC) correlates between the power demand and the solar power generation. The six profit-making

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PV technologies have been analyzed and found that even with the thin film amorphous silicon PV modules of minimum efficiency, the urban areas could accommodate 30% PV infiltration in the worst case (vertical, high-rise urban area). The higher PV penetration could be accommodating for residential horizontal areas. In residential horizontal area the ELCC is lower as compared to commercial areas [33].

It has been concluding that the optimum placement of DG is very important for reducing the power loss and voltage sag. VSI is an integral part of the calculation for optimum placement of DG. As the BH increases the THDv at node bus also increases.

IV. TECHNO-ECONOMIC FEASIBILITY

The techno-economical practicability analysis is very important for distributed energy resources to generate power efficiently at any particular location. This analysis includes the assessment of technological advancement, profit making and other financial incentives provided by the particular country.

The economic growth of a grid-tied PV system leans on PV array capacity, the inclination of PV module, the angle of the array, building load profile, utility tariff, feed-in tariff, PV/more inert capacity ratio, and PV/inverter cost ratio. The fractional load provided by the PV system leans on matching between power supplies by a photovoltaic system, premises load structure, capacity ratio and tilt angle of PV array. When the feed-in tariff is lesser than the utility tariff, the grid connected PV system can be profitable only when the PV system sized to minimize the surplus PV power supply to the grid. The expenditure on PV power leans on the life time of PV array and inverter, capacity proportion, cost proportion, angle of PV array and financial parameters. When the cost proportion lies between 7-11, the effect of cost proportion on the optimum PV/inverter capacity proportion is lower. At low radiation condition, the PV power cost is minimum for the sizing proportion of 1.6 and at large radiation, the PV power cost is minimum for the sizing ratio of 1.2. For some selected European countries, the cost of PV power is minimum for surface slopes within 30^0-40^0. The economic analysis of various methodology used for flowing the yielding power of broad PV system has been performed. The result shows that whatever the method used for flowing the yielding power of PV system there is revenue loss as compared to the case which is without the smoothing system. For long-term economic aspect, the expensive NAS battery energy storage proved to be exceptional to the low-cost LA batteries; this is due to the longer life and higher efficiency of NaS battery. The power rating of battery does not affect by increasing the duration of operation of the battery in morning and evening hours. However, it has found that the deficit in revenues rises with a decrease of power fluctuation constraint. This is due to the fact that by decreasing the power fluctuation limits, the power and energy rating of the battery increases. The revenue loss will be lower by curtailing the active power below the maximum power point (MPP) operation and bypassing the extra power to meet the power fluctuation constraint. Combining power curtailment and battery energy storage system is found to be the most economical solution [34], [45].The technical scope of solar photovoltaic in Bangladesh has been assessed through GeoSpatial toolkit, solar radiation data taken by NASA and HOMER optimization software. Economic potential has been assessed by using a suggested 1-MW grid-tied solar PV system using Rescreens simulation software. The internal rate of return, net present value, benefit-cost ratio, the cost of energy production and simple payback, are the economical and financial factors have been calculated. These entire indicators show a favorable result for the development of solar PV. By using renewable energy resources it has found that 1423 tons of GHG reduce the burden on climate change [30-31].Techno-economical analysis of several types of voltage control strategies of Low voltage grid with high PV infiltration has been studied. The control strategies include active and reactive power control of PV inverter and OLTC transformer. The methodology presented here compares the technical benefits of these control strategies. Among these control strategies, the OLTC showed maximum benefits as it enables more voltage rises on the feeder. By the application of autonomously controlled OLTC and PV inverter, the cost reduction of distribution system operator (DSO) reduces up to 75% for 10 years. The annual PV feed in loss reduces significantly by using the voltage-dependent active power curtailment instead of fixed percentage of curtailment. By using coordinated control approach, the network loss minimization potential is very low which offers the insignificant economical potential to the DSO [35], [46].The inclusion of LA battery in grid-tied domestic PV generation for charging the battery during cheap power export and discharge to the grid during peak hours cannot recover the financial expenditure even with the idealized lossless batteries with optimistic lifetime. The practical LA battery developed have to charge and discharging efficiencies of 39.1%, 53.0%, and 58.5% for 210 Ah, 430 A h, and 570 A h respectively. Even with these efficiencies and expected

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lifetime taking into account, the financial return still worse. The production and use of lead acid battery further offer a negative impact on the environment [36-40].General algebraic modeling system (GAMS) has been used to solve the optimization model developed for the microgrid. Uncertainty in demand and supply has been simulated and the sensitivity of battery capacity has been conducted for economic analysis. More the value of battery capacity, more investment is required and so installation of more storage devices might not be profitable. The future scope of study includes multi-criteria optimization of carbon dioxide reduction, cost effectiveness, and energy optimization [41-43].The profit making competitiveness of grid-tied roof top distributed solar photovoltaic generation in five Brazilian state-capitals has been conducted. Levelized electricity costs (LEC) for PV generation and net present values (NPV) for a specific PV system have been presented [44].
It has been concluded that the economic growth of a grid-tied PV system leans on PV array related factors such as capacity, inclination, and building load profile. Utility tariff, feed-in tariff, PV/more inert capacity ratio, and PV/inverter cost ratio also affects the economic viability of grid-tied SPV.

V. CONCLUSION

The following conclusions have been taken from the thorough study of the literature available on optimal operating strategies of distributed power generation integrated with microgrid.
(i) SPV can be optimized by regulating the charging and discharging rate of the battery to control the variation of real power while integrating with the smart grid.
(ii) By using the droop control method for regulation of varying reactive power and frequency, the threat of SPV integration can economize.
(iii) To maintain the node voltage stable, two control methods are advised to use such as unity power factor method and the constant voltage control. Usually, the unity power factor control operates but when the node voltage rises more than the limit, another control starts.
(iv)Techno-economical analysis of several types of voltage control strategies of Low voltage grid with large PV infiltration has been discussed.
(v) The control strategies include active and reactive power control of PV inverter and OLTC transformer.
(vi)The methodology presented here compares the technical benefits of these control strategies. Among these control strategies, the OLTC showed maximum benefits as it enables more voltage rises on the feeder.
(vii) By the application of autonomously controlled OLTC and PV inverter, the cost reduction of distribution system operator (DSO) reduces up to 75% for 10 years.

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