Smart Electrification of Rural Bangladesh Through Smart Grids

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Abstract A smart grid is a new technology that integrates power systems with communication systems. It is an intelligent and efficient management system that has self-healing capabilities. The smart grid can be applied to manage networks that integrate different types of renewable resources for power generation. Bangladesh is currently experiencing severe power deficiency. Renewable energy sources such as solar power and biogas can play an important role in this scenario, especially in rural areas where electricity is even scarcer. By applying prototype concepts of smart grid, power generation from renewable resources and efficient load management can be achieved by a centralized control center. This will control the on-off sequence of the load and maintain the system stability. In this paper, different aspects of implementing a prototype of the smart grid in the rural areas of Bangladesh are discussed.

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1 Introduction

Capability in electrical power generation is a major driving force towards socio-economic development of a country. For a developing country like Bangladesh, the electricity capacity of power generation is far less than the demand [1, 2]. Therefore, to cope with the rapidly escalating demand for electricity, rigorous attention needs to be provided to generate electrical energy from renewable energy sources [3]. Rural areas of Bangladesh have limited access to the electrical power supply from the national grid compared to the urban areas [4]. People living in rural areas which do having electricity encounter frequent power shortages [4]. Solar photovoltaic (PV) systems are widely implemented in these areas [4]. To provide electricity in rural areas with renewable resources, a prototype of the 'smart grid' concept can be considered. This approach can lead to cost-effective deployment, efficient operation and good maintenance of the deployed system [3]. Some aspects of the smart grid systems can be implemented in this type of approach. This paper provides a discussion on how a basic framework of a smart grid system can be used to achieve control strategies and well-organized operation of a prototype system that incorporates renewable resources in rural areas of Bangladesh. The existing power system situation is discussed first as well as the current state of renewable resources of Bangladesh. A brief overview of the framework of a smart system is provided afterwards. Challenges of integrating renewable resources are highlighted. Finally, the different aspects of implementing the prototype using smart grids concept are discussed.

2 Existing Power Scenario of Bangladesh

Bangladesh, a low-income developing country [5], is highly vulnerable to setbacks arising from the ongoing electricity crisis. Natural gas, the main source of fuel for energy generation, is responsible for around 72% of the total commercial electricity consumption and around 81.72% of the total electricity generated [6, 7]. But, studies show indicate that the gas demand will increase up to 4,567 mmcfd by 2019–2020 [8] resulting in a shortfall of around 1,714 million cubic feet per day (mmcfd) [8]. Even if a slow growth rate of GDP is considered as 5.5% till 2025, Bangladesh will need about 19,000 MW of additional power each year [8].

Solving the ongoing electricity crisis was one of the major issues in the election manifesto of the current government [8]. The government focused on Quick Rental Power Plants which run on diesel fuel. Initially, it was able to reduce the gap of generation and demand for electricity, but the fuel cost made the cost of electricity considerably higher [9]. Due to the latest rise in oil prices in the international market, government subsidies for petroleum-based power plants went up. As a result, the price of electricity per unit was increased three times within just four months. Cost per KW-hr of electricity rose from TK 4.16 (USD 0.051) to TK 4.72 (USD 0.058) on December 1, 2011, then to TK 5.02 (USD 0.061) on February 1, 2012 and finally to TK 5.32 (USD 0.065) on March 1, 2012 [10, 11]. The average production cost of a unit of electricity is Tk 5.70 (USD 0.070), according to the Bangladesh Power Development Board (BPDB) [9].

As a developing country, it is not surprising that Bangladesh depends quite heavily on coal to produce electricity [1]. In the short term road map to meet energy demand by 2015, the Bangladesh government had contracted almost 2600 MW of coal fire power plants in Chittagong and Khulna [1]. A study of carbon emission shows that carbon dioxide emission rate (Metric tons per capita) increased very rapidly from 0.2 in 2005 to 0.3 in 2008 [3]. These developments current developments in power generating plants will make Bangladesh more vulnerable to high carbon emission.

System loss is another major problem for power systems in Bangladesh. This consists of the line loss, heat loss, unaccounted energy usage and electricity theft. System loss affecting public utilities is a persistent problem in Bangladesh's infrastructure. According to BPDB, the overall system loss calculated in 2008–2009 was 6.58% of net generation [1]. The monthly system loss for various months of the year of 2011 in Dhaka, based on information provided by Dhaka Electricity Supply Company Limited (DESCO) [2] is shown in Fig. 1.

The inefficiency of the overall transmission and distribution system, shortage of gas, unavailability of some power plants from time to time due to maintenance,

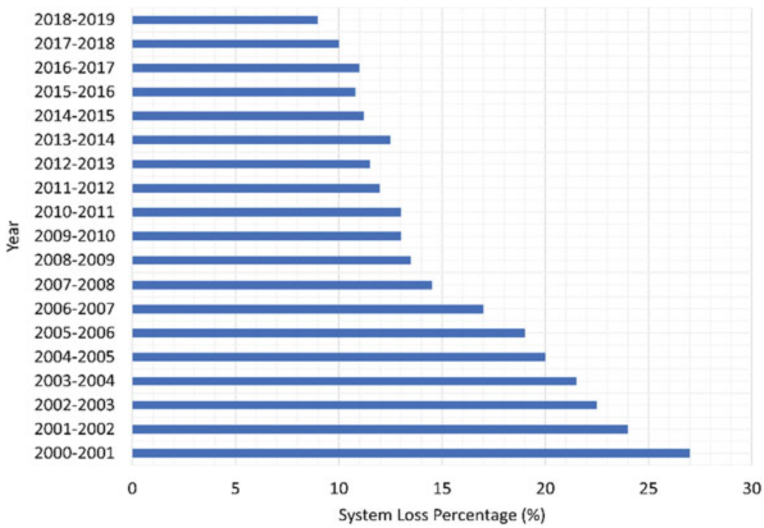

Fig. 1 System loss percentage in Bangladesh from 2000–2019 [2]

rehabilitation and overhauling, degenerated capacity due to aging of power plants are also some other problematic issues for the power system in Bangladesh [1].

The dependency on natural gas, oil and coal as well as abovementioned issues have changed the focus to renewable energy resources. Biomass, Biogas, Solar, Hydropower and Wind are the potential sustainable sources of energies. Energy security, as well as a cost-efficient and effective power supply to the off-grid rural areas of Bangladesh, can be provided if electricity can be harnessed from these renewable resources [3]. It is therefore imperative to study the renewable energy scenario of Bangladesh.

3 Renewable Energy Scenario in Bangladesh

To meet the existing deficit in power generation, renewable resources are becoming more attractive alternatives in Bangladesh. As a result, a policy for the effective utilization of renewable energy resources has been adopted by the Government of Bangladesh (GOB) [3]. The focus of this policy is to shift the considerable dependency on conventional fossil fuel-based thermal power plants. Global depletion of fossil fuels, increasing cost of purchasing and importing as well as a desire to move towards clean energy are the main driving forces behind it. So, the necessity of harnessing energy from renewable resources is essential. Among different types of available renewable resources in Bangladesh, the most potential ones which be explored rigorously by Bangladesh are discussed below.

3.1 Solar Energy

The abundance of solar radiation (daily 4.0–6.5 kWh/m^2) [12] has enabled the potential growth of solar-based energy resources in Bangladesh. The months of March to April and the months of December to January provide maximum and minimum solar radiation respectively [13]. Photovoltaic (PV) solar systems and Concentrating Solar Power (CSP) systems are the most common technologies. PV solar systems have been implemented extensively throughout the country, mostly in rural areas [3]. 801,358 Solar Home System (SHS), having a capacity of 36.5 MW, had been installed by January 2011 [3].

3.2 Biomass Energy

Bangladesh is an agricultural country. So, biomass is the most notable energy source in Bangladesh as biomass covers all types of organic matters which are available from a different type of crops. Biogas plants also use animal wastes from dairy and poultry farms. 70% of total final energy consumption is produced by biomass in Bangladesh [14].

3.3 Wind Energy

Wind energy generation has some prospects in the coastal areas of Bangladesh. The average wind speed available in coastal areas is 6.5 m/s and the density of wind power varies from 100 to 250 W/m^2 [15].

3.4 Hydro Energy

Bangladesh is a land of rivers. Approximately 1.4 trillion cubic meters of water per year flowing through different rivers. Even though the land is fairly plane, high current flows through major rivers for six months of the year which provides some locations with the prospect of 10KW to 5 MW power generation capacity [3].

Based on a study by Kaiser et al. [16], the relative contributions in terms of installed capacity in MWp for five renewable resources in Bangladesh are shown in Fig. 2. From the chart, it can easily be interpreted that solar and biogas are playing the most significant role. So it can be concluded that for rural areas, solar power can be the obvious choice for the main power generation source of a prototype grid where some technologies of smart grid concepts are implemented. For the successful implementation of this type of approach, the basic elements of the smart grid need to be reviewed.

4 Framework of Smart Grid

A smart grid is an intelligent network that uses digital and other modern technologies to observe and supervise the transportation of electricity from different generation resources to meet the dynamic electricity demands of the customers. Smart grid manages the requirements and capacities of all parts of the system including generators, grids, and customers as efficiently as possible. As a result, it minimizes costs and environmental impacts and maximizes system stability, reliability and resilience [17].

Smart grid helps to operate and proficiently manage the existing grid. The integration of a bi-directional communication system integrated with the power system is the most unique feature of the smart grid. Perhaps the most important feature of a smart grid is the ability to dynamically integrate the variable renewable resources which helps to reduce carbon emission and assists to meet the future power demand [18]. To maintain the balance of supply and demand, it also includes a storage system.

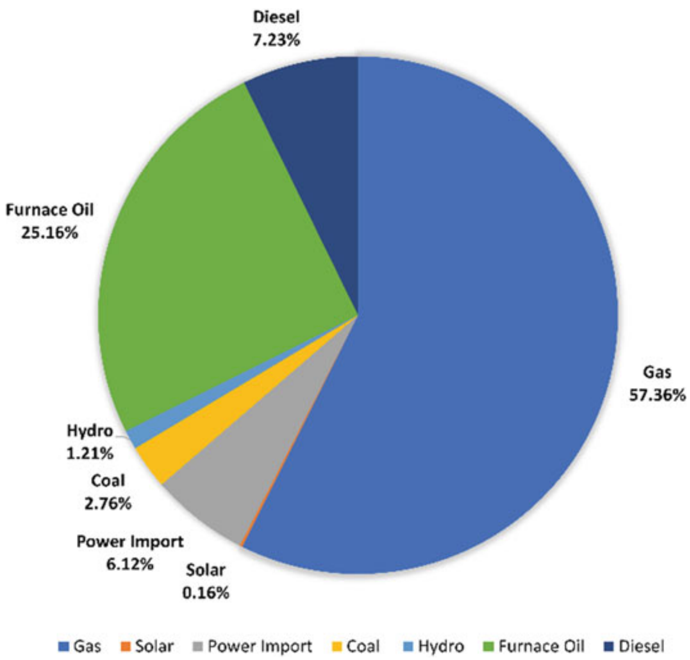

Fig. 2 Contribution of different implemented renewable energy technologies in Bangladesh in the year 2019 [2]

It is equipped with a real-time metering system that allows customer interaction facility, dynamic tariff system and demand-side management. Self-healing feature is an important characteristic of a smart grid. To maintain the stability of the system, the operators can manage the distributed resources to provide reactive power, voltage support and other ancillary services using the two-way communication infrastructure of the smart grid [19].

The technological improvements in the areas of communication, control and sensor technology are enabling the gradual implementation of a smart grid all over the world. The existing grids need to be updated with modern technological advancements for the transformation towards a smart grid. A standardized bi-directional communication system is the first area that needs to be updated. Integration of improved power electronics and measurement devices is also an integral part of a smart grid. An appropriate control method needs to be developed and implemented for the successful application of smart grids [20, 21]. The proposed prototype system borrows these features of smart grid technology along in addition to some other elements.

5 Smart Grid Prototype for Rural Areas of Bangladesh

Solar power is the most prominent source of renewable energy in Bangladesh [16]. For rural areas of Bangladesh, the Solar PV systems are most widely used. The goal of this smart grid prototype system is to provide electricity to a group of rural households of Bangladesh with the Solar PV system (Fig. 3).

5.1 Structure of Smart Grid Prototype

A stand-alone solar PV system consists of a solar panel, a charge controller circuit and a battery [22, 23]. As our existing system is an AC grid, the electricity obtained from the solar PV system is fed to the inverter before reaching to the load [23]. In case of a DC grid, the electricity can be directly provided to load.

Renewable source of energy, that is the solar PV system, will be connected to the grid through a charge controller circuit. Depending on demand and generation, the charge controller circuit will control the charge flow to the energy storage device and the load. During high demand, available electricity will be directed to the load. During excess generation, the controller circuit will charge the battery so that this energy can be used later. Also, the controller circuit will charge the battery if the

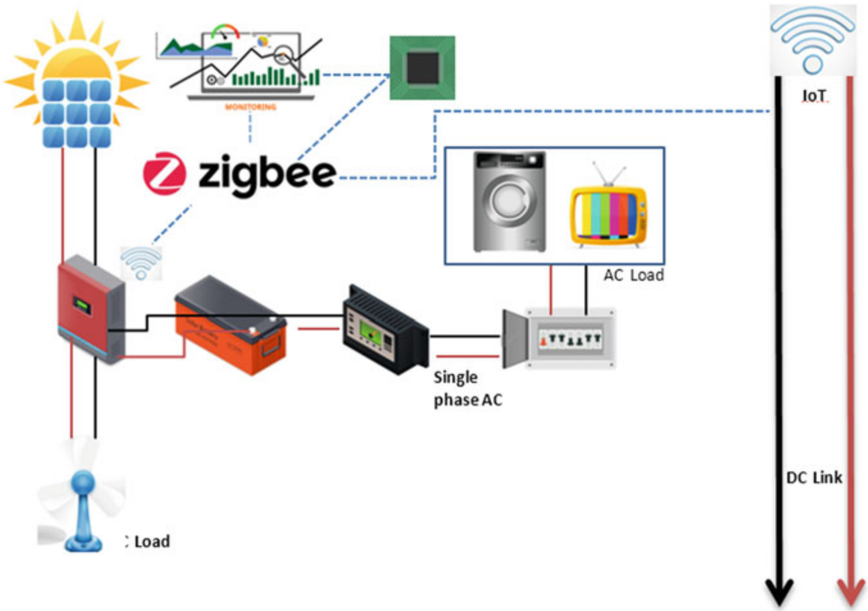

Fig. 3 Overview of a smart grid prototype for rural Bangladesh

charge level falls below the threshold value of the battery. When there is a generation greater than the rated value, the controller circuit can trip to protect the devices as well [24]. The electricity produced is connected to the distribution system. A Central Control Unit (CCU) controls the total system. It includes communication devices, monitoring devices and decision-taking system.

The communication with other devices can be maintained with a wired or wireless connection. Wireless communication systems can include Zigbee and IEEE 802 based standards for short-range and moderate range applications respectively [25]. Power Line Communication (PLC) system can be implemented for the wired system. These components will have a built-in modem. All the components will be communicating with the CCU using the modems. Communication is one of the most important parts of this system. So, it needs to be ensured that the communication links among the modems have minimal channel errors and thus high reliability.

The monitoring system will be composed of different measuring devices. These devices will measure different parameters such as voltage level, current, energy usage, generation, demand, etc. Since the loads are not sensitive, the measurements will be taken and transmitted to CCU periodically. This will result in a less complex system.

The decision-taking system of CCU will analyze these data. Based on it, it will take decisions that will be transmitted to respective components through modems. So, necessary actions will be taken corresponding to current parameters for efficient operation and management. For successful operation of the prototype, several other applications are also required.

5.2 Prototype of DC Grid

Since a solar PV system is applied, hence DC power will be generated. So, a prototype of the DC grid is required. The solar panel will be connected to a charge controller circuit which will be then connected to a DC grid through an energy storage device like a battery. The DC grid will be connected to loads through inverters which will convert the DC power to AC. All the inverters will be connected with CCU. Figure 4 shows the setup of the prototype DC grid. DC transmission system is preferred over AC transmission due to its higher efficiency. Only loss got is at the conversion of DC-AC. This is about 5–10% of the generated power. As micro inverters are used the loss will be towards the lower side of the band.

5.3 Synchronization of Voltage, Frequency and Phase

Synchronization of voltage, frequency and phase is an imperative aspect of this system. The inverters need to be synchronized before connecting them to the grid. A load and its associated inverter will be taken as reference node by the CCU. All other inverters will be synchronized corresponding to this inverter by CCU. The CCU

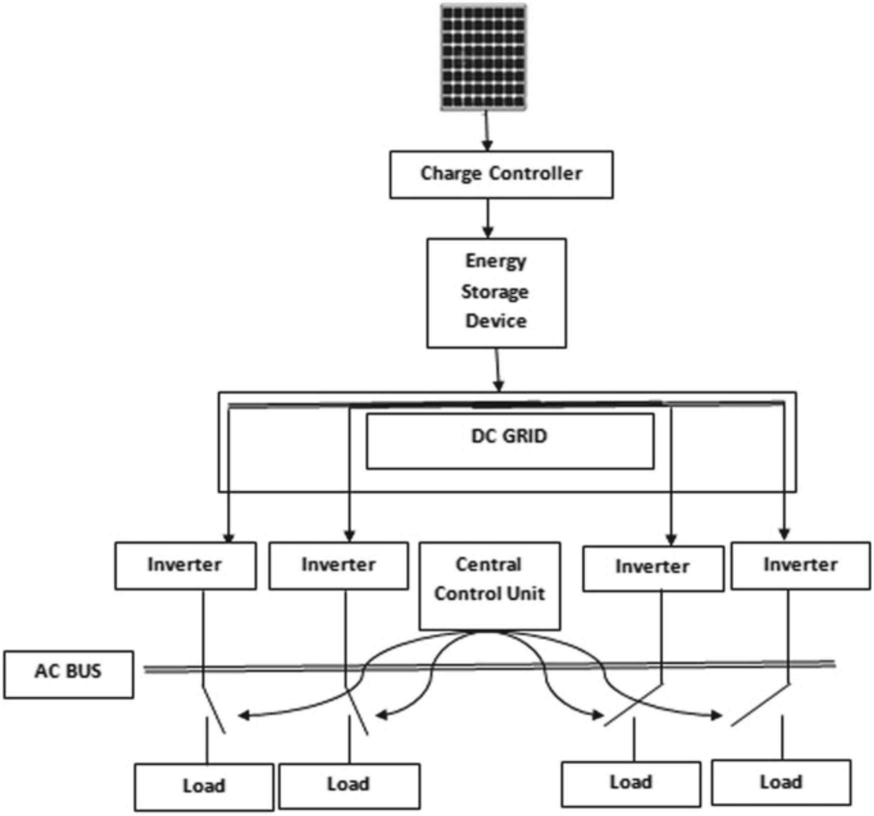

Fig. 4 Prototype of DC grid

will measure the voltage level. There are multiple inverters in this system each one connected to DC link. Each inverter is driving different load in the network. CCU controls the on-off sequence of these inverters according to the demand. Multiple inverter system has been proposed for this system to increase the reliability of the system. A central big inverter can go down even if one solar panel does not function properly whereas micro inverter diminishes this problem.

The control algorithm can be expressed as below.

- Initialize the reference inverter out of 'N' inverters and assign its index $i = 0$. Turn off all the switches at other loads.
- Measure the voltage (v), frequency (f) and phase (Ø) of each inverter and transmit to the CCU:
  $\{F\}_i = \{v, f, Ø\}_\mathrm{i}$ where i = 1, 2,3 … … … (N − 1)
- while $\{F\}_\mathrm{ref} \neq \{F\}_i$ do
  if $\{F\}_\mathrm{ref} < \{F\}_i$ then $\{F\}_i = \{F\}_i - \Delta\ \{\mathrm{F}\}_\mathrm{i}$
  where $\Delta\ \{F\}_i$ = step size

elseif $\{F\}_{\text{ref}} > \{F\}_i$ then $\{F\}_i = \{F\}_i + \Delta\,\{F\}_i$
else turn on the switch.
end while

- Transmit the decisions to the sensors at each load.

This control algorithm can also be applied if an inverter goes out of synchronization due to a major disturbance.

Voltage, frequency and phase of an incoming node and compare it with the reference node. Then CCU, using a control algorithm, will instruct the new incoming node to match its measured parameters till synchronization is achieved. This process is similar to the concept of micro-grids [26].

5.4 Control of Harmonics

The inverters can produce harmonics. To mitigate its effect, the CCU will periodically measure the voltages from the measuring devices connected at each inverter. Based on this, the CCU will perform a harmonic analysis and take appropriate measures to control the harmonics within an acceptable level [27].

5.5 Managing the Prototype with Hybrid Energy Sources

Diesel generators are the cheapest and the most easily available generators in Bangladesh [4]. It is widely used in rural areas for irrigation as well as supplying electricity during load shedding [4]. Since there is a lot of power shortage in rural areas, the people in these areas use diesel generators as back up source of electricity if they can afford it [4]. The prototype can have hybrid energy sources by including a diesel generator with renewable energy resources. This diesel generator can be used as a backup unit to provide electricity to the system when the load demand is higher than the capacity of solar PV sources. It can also be used to charge the battery when the battery voltage becomes low and there is no solar power available to charge the battery. Since a diesel generator is an AC source, it cannot be connected to the DC grid directly. So, a rectifier needs to be placed in between the DC grid and diesel generator. Traditionally, the diesel generator is turned on manually when it is required. But this can be done automatically as well by using a smart controller circuit. The smart controller can measure the voltage level of the solar PV system and load demand and based on that the smart controller can take decisions by itself whether the diesel generator should be turned on or not. Sensors placed on the battery will transmit the voltage level of the battery to the controller. The controller will compare this value with a threshold value. If the measured voltage of the battery is less than the threshold value, a smart controller will turn on the diesel generator. If the operating load goes beyond the rated value of the solar PV system, the measured value will be transmitted to the CCU which will switch off the loads. When there is low demand, like after midnight and when the charge level of the battery is also low, the diesel generator can be turned on to charge the battery. Since Biogas is also largely available as a renewable resource in rural areas [16], it can also be incorporated with the solar PV system in future.

5.6 Synchronization for AC Grid

The synchronization process for the prototype of the DC grid has been discussed previously. The similar approach can be followed to synchronize the inverters of multiple solar PV systems. These inverters need to be synchronized prior to their connection to the grid. Different operating parameters of these inverters will be transmitted to the CCU. The CCU will then compare these values with the reference node values and synchronize the inverters by instructing them to match the parameters.

5.7 Incorporating Irrigation Pumps

Bangladesh is an agricultural country. So, there is a lot of demand for irrigation pumps. This demand even gets even higher during the dry summer seasons. As a result, a lot of power outage takes place during the dry season when load demand in city areas, as well as rural areas, increase altogether. The irrigation pumps are mostly induction motor-based pumps [4]. As have known, the characteristic of the induction motor is to draw a large starting current. Solar PV systems are sometimes used to power these irrigation pumps [4]. So, the large starting current of the induction irrigation pumps can exceed the rated current values of solar PV systems [4]. The prototype system can accommodate this scenario. When the pumps are turned on, the sensors will transmit the signal to CCU. The CCU can monitor the current level and manage other operating parameters to accommodate the large staring current. It can also switch off other loads and turn on the diesel generator if required.

5.8 Protective Mechanism

Self-healing characteristic is an important aspect of smart grid systems. The prototype system can incorporate this idea. Since the prototype system has sensors all over which communicate with the CCU, the prototype system can sense the irregular operating conditions and take required remedial actions. The prototype system will be capable of detecting over-voltage or under-voltage conditions of the sources. When the demand gets too high, the CCU can manage this situation by adding more sources on the generation side. It can also manage the system by switching off some loads, which is also known as load side management. The prototype system will be equipped with the ability to provide reactive power support to the grid. To increase the protection of the total system, a coordinated protective relay system will be implemented as well. Frequency droop regulation technique should be implemented in the system to provide the real load (KW) sharing [28].

5.9 Load-Energy Economy

Demand-side management is an integral part of the prototype system. This helps to maintain the balance of generation and demand. Public awareness has to be created to ensure the efficient use of electricity. The people need to be educated and informed about when to use what type of devices. Users should be encouraged to change their habits to reduce the wastage of electricity. Sometimes, people keep electrical devices turned on even if they are not required. By creating public awareness, these types of behaviours can be changed. Also, users should be aware of peak demand periods. They should be encouraged to use less electronic devices during peak hours if possible. This will reduce and shift the peak demand and hence accommodate low generation during high demand [29].

5.10 Local Energy Economy

The local-energy economy will help the users under the prototype system to manage their load. When generation balances the demand, the price of electricity will be low [30]. But when demand is higher than a generation, power has to be bought from the grid or it has to be generated using the diesel generator. This is most likely to be at a higher price [30]. Also, excess generation from solar PV can be sold to the grid or used to charge the battery for later use. The difference in the price of generating power between the solar PV system and grid & diesel generator will encourage the more responsible application of demand-side management by the users [30].

6 Smart Grid and the Internet of Things (IoT)

The Internet of Things (IoT) is a breakthrough technology using which surrounding objects are connected through wired or wireless networks without any user intervention. The objects then become capable of communicating and exchanging information among themselves as well as to any servers that are available through local networks or public infrastructure such as the Internet. The information that

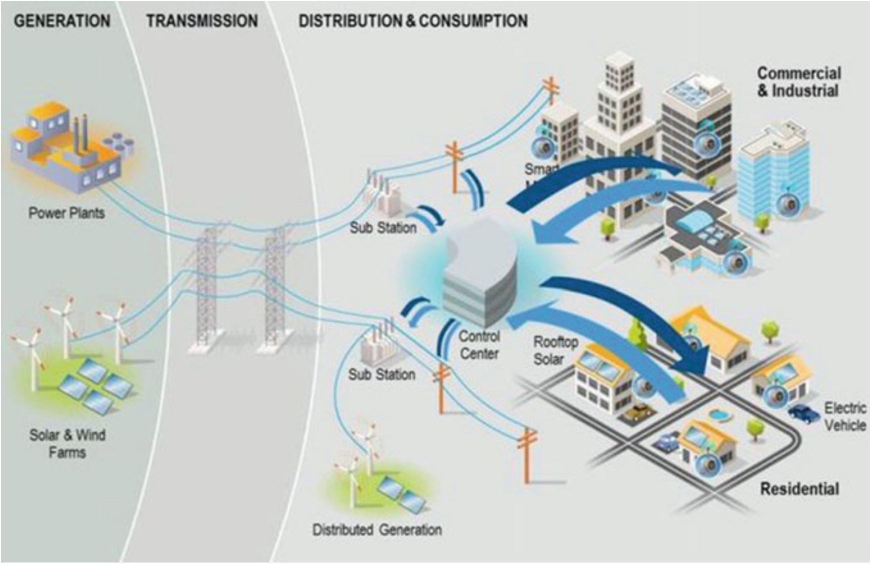

Fig. 5 IoT-based smart grid [32]

is collected and analyzed through multifarious IoT devices can offer advanced intelligent services to users [31].

In any Smart Grid setup, as shown in Fig. 5, application of IoT is vital, as it integrates almost in every sub-part of a Smart Grid, from power generation to distribution. Even at the users' end, various aspects of power consumption can be effectively quantified and enhanced, bringing a range of benefits to not only the power distributors but also to the user base.

Transformers are a key component in electricity distribution and transmission for recalibrating the source voltage for customer use. IoT enabled sensors can be installed internally to gauge operating parameters such as temperature, current, oil level fluctuation and even real-time environmental humidity and unit vibration [33]. All parameter values can be transmitted to monitoring stations through GPRS in real-time. This instantly alerts the monitoring stations in case of any emergency occurrences.

Further, sensor-enabled IoT based Power Meters, placed in any household that has basic home network-enabled, can collect many parameters from different devices in the household that uses electricity. This data can then be put to use for analyzing electricity usage, calculate billing information, make real-time decisions on load distribution, recognize detect unwanted malfunctions and even risks of probable outages. In addition, the power wastages can also be separately calculated, which can have a strong positive effect in reducing the overall monthly bill [34].

There were just a few of the examples of how IoT empowers a Smart Grid setup. IoT devices can further be placed into almost at any point of a Smart Grid and can amass a massive range of critical operating information. Such large datasets of information can also be processed using state of the art machine learning algorithms [35] to generate prediction patterns. Such advanced analytics can not only bring considerable improvement in service and cost savings but also can enable automatic fault-tolerant processes within various internal equipment [36].

7 Conclusion

The increasing price of electricity, rising power demand, and significant generation deficit is driving Bangladesh to move towards renewable resources. Different types of renewable resources are now being explored and implemented as an alternative source of energy, especially in rural areas. Instead of managing these systems centrally, it will be more effective to manage these resources on a small scale. A prototype of a smart grid as discussed in this paper can ensure the intelligent and autonomous management of supplying power from renewable resources to a few households in rural areas. It can also control the load side more efficiently and thus contribute to the solution of the energy crisis in Bangladesh.

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Dissimilar Disease Detection Using Machine Learning Techniques for Variety of Leaves

Varshini Kadoli, Karuna C. Gull, and Seema C. Gull

Abstract Agriculture is one of the main sectors in which about 70% of the population is dependent on, in India. The leaf disease detection would help the agriculturist in knowing whether the plants are affected by the disease before it could spoil the entire plantation. The method proposed helps in the early detection of leaf disease if the plant is affected. Advance machine learning has been used to determine the same by taking the diseased leaf image as an input. The system adopted with *K*-means clustering and the support vector machine classification technique after proper training is utilized for testing any plants' leaf diseases. The accuracy of the result obtained is in the range of 85–88%.

Keywords Image processing methods · Machine learning (ML) · Classification · Support vector machine (SVM) · Standard deviation (SD) · K-means clustering · Accuracy

1 Introduction

Developing world population has brought a ton of weight on rural assets. It is basic to get the greatest yield from harvest keeping in mind the end goal to support the populace and the economy. Plant diseases are the primary wellspring of plant harm which brings about financial and generation misfortunes in agrarian ranges. Inferable from troubled climatic and ecological conditions, an event of plant illnesses is on the ascent. There are different sorts of diseases in plants, the assortment of side effects,

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for example, spots or smirch emerging on the plant leaves, seeds and stanches of the plant. Keeping in mind the end goal to deal with these elements viably, there is a need to present a programmed strategy for plant observation that can examine plant conditions and applied information-based answer for recognition and groups them into different infections. Machine Learning is one of the distinguished methods for a proper structure to bolster this issue.

The proposed work includes the impression of image processing, where an input provided is an image, and the output might be an image or attributes of the image which helps to quantify input image. "An image is an array, or matrix, of square pixels arranged in rows and columns." As the image is a two-dimensional array, normally an advanced image is eluded as image components or pixels. Each pixel in the image is recognized by one or more numerical qualities that ultimately lead to being the characteristics of the image. For grayscale images, a solitary quality recognizes the force of the pixel. The intensity range can be of [0, 255] range. For color images, "image handling is a multidisciplinary field" [1]. It additionally concerns different regions, for example, machine learning, counterfeit consciousness, human vision research and so on.

1.1 Motivation

Due to the extreme climatic and ecological conditions, plants usually get affected by certain diseases. Leaf disease detection would help in identifying whether the plant is affected by the disease by its leaves. Advancement in technology, the way interacted with the environment, is also changing. This change can influence us to get better in each and every field including image processing technique. Exploring the connection between the physical and digital world may help the farmers. The method of detecting leaves diseases provides a helping hand to the agriculturists. It may give the farmers the best way of knowing about the health of the plant that they are yielding in the field. Machine learning is one such method that helps in detecting the disease in the leaves.

1.2 Problem Statement

To emerge automatic disease detection, a tool takes the leaf image as an input and enhances the image by applying different enhancement technique. Later, segmentation operation is applied to an enhanced image utilizing the k-means clustering algorithm. Features are extracted from the clustered images. Based on these features, the leaf is classified as either diseased or healthy using support vector machine. Thus, to find healthiness of a variety of leaves, a method is proposed as "dissimilar disease detection using machine learning techniques for a variety of plants' leaves."

2 Literature Survey

The proposed method has been obtained after going through the papers.

Apple leaf disease is one of the main problems that [2] have become the constraint in the growth of an apple. Apple leaf disease detection is done using image processing techniques and pattern recognition techniques. A color RGB input image of the apple plant is taken and then converted HIS, YUV and gray models. The background was then later removed using a threshold value and the spot segmentation was done using region growing algorithm (RGA). Around 38 classifying features were extracted based on color, texture and shape. The most valuable or the features considered important was extracted by combining genetic algorithm (GA) and correlation-based feature selection (CFS) to reduce the dimensionality of feature space and improve the accuracy of apple leaf disease detection. Finally, the SVM classifier is used to identify the disease that occurred in the apple leaf.

It explores the various imaging techniques. [3] These are developed mainly with a motto on deployment for monitoring methods for plants or crops. Classification of plants is done whether one is a healthy or diseased plant. It is expected to be accurate and the diseased plant should be detected as early as possible to help the agriculturists. Hyperspectral imaging has been used for the review. It is further used to provide additional information about the plant.

Machine learning is an advancement that has been in used in present days [4]. It is now developing and reduces the human effort and it comes under the field of computer vision. The diseases caused have a dangerous impact on agriculture. So a method is developed to detect the leaf disease. Normally, a plant is said to have a disease if it is affected by the pathogens such as bacteria, fungi and virus. Prediction for earlier detection has been used. This is done by using machine learning. Deep learning algorithms are also further used to detect the same. It acquires the data for the detection and the data is being stored in the cloud. It goes through the stages like image acquisition, image segmentation, feature extraction and classification. It also has to recognize the plant and hence the disease it has been affected. The output obtained is in the form of graphical visualization.

Spectral imaging has been in use within breeding because of the utility as a non-invasive diagnostic tool [5]. Canopy-scale measurements have resulted in low precision. It mainly tries for a prototype for the design that is a multi-spectral system for the study of plants. This analysis mainly takes machine learning into account for feature selection, disease detection to carry on with the classification. It further helps in the improvement of the system. The proposed model produced accurate results up to 92% when imaging was done for oilseed rape plants. False-color mapping of vegetation was used. The structure of the plant was further recorded using photometric stereo. The shape of the plants was also recorded. This allowed for the reconstruction of structure and leaf texture. The importance of this is to capture the structural information with the effect of reflectance and classification. This could be used in plant breeding with the quantization capability.

Evaluation in cluster analysis produces different clusters when used in diverse clustering techniques [6].

The distance between data vector x and centroid v is computed as using various measuring techniques.

The suggested depends on your dataset and output required that choose the proper distance measuring method with K-means to get the required output.

The feature set obtained is used for robust visual object recognition and identification [7]. The classifier used is SVM-based identification. The test case used here is human detection as a test case. The existing edge and gradient descent-based error detection are used for description. Histograms of oriented gradient (HOG) have been used for the test case as mentioned. This new approach has been an improvement in technology and hence gives a near-perfect classification of the pedestrian database including the pose variations of the human beings.

Euclidean distance:

$$D(x, v) = \sqrt{\sum_{i=1}^{n}(x_i - v_i)^2}\sqrt{\sum_{i=1}^{n}(x_i - v_i)^2 ss} \quad (1)$$

Manhattan distance:

$$D(x, v) = \sum_{i=1}^{n}(x_i - v_i)\left\|\sum_{i=1}^{n}\right|(x_i - v_i)| \quad (2)$$

Chebyshev distance:

$$D(x, v) = \max|(x_i - v_i)| \quad (3)$$

Chi-square distance:

$$D(x, v) = \sqrt{\sum_{i=1}^{n}\frac{(x_i - v_i)^2}{(x_i + v_i)}}\sqrt{\sum_{i=1}^{n}\frac{(x_i - v_i)^2}{(x_i + v_i)}} \quad (4)$$

Raspberry Pi has been used as a controller to detect plant diseases and prevent them from spreading [8]. For image analysis, K-means clustering was done. According to the research, the leaf ailment was necessary to be recognized since it automatically detects symptoms of the plant diseases by K-means clustering in image processing. It has been useful for upgradation. It recognizes the diseases by using the particular picture and then providing the information by email, SMS. Automatic detection of diseases by its symptoms is done which would reduce the use of pesticides and hence increase the productivity in the farm.

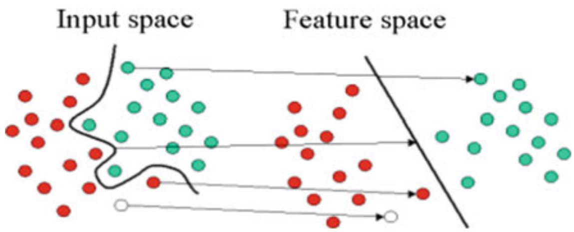

Fig. 1 SVM basic operation (Anon. 2011)

The authors explained the support vector machine [9] algorithm with the objective function.

$$C\sum_{i=1}^{m}\left(y^{(i)}\cos t_1\left(\Theta^T x^{(i)}\right)+\left(1-y^{(i)}\right)\cos t_0\left(\Theta^T x^{(i)}\right)\right)\ +\frac{1}{2}\sum_{j=1}^{n}\Theta_j^2 \qquad (5)$$

where θ is the parameter vector, x is the feature vector, n is the number of features, m is the number of training sets, C is the regularization parameter, $\cos t_1\left(\Theta^T x^{(i)}\right)$ and $\cos t_0\left(\Theta^T x^{(i)}\right)$ are the costs when $y = 1$ and $y = 0$, respectively.

A basic representation of how it splits the data is shown in Fig. 1.

They said that for a given dataset, there may be multiple possibilities of hyperplanes but the SVM algorithm chooses the one that provides the greatest margin or the maximal margin between the classes. It is one of the sophisticated classification methods with high classification accuracy which made it so popular.

The process of classification of pomegranate leaf detection was done using image acquisition, image preprocessing and image segmentation, and thus, feature extraction was done [10]. The classification followed the method of support vector machine (SVM). Spatial filter, K-means clustering, GLCM were the additional techniques used to produce 90% result.

3 Proposed Methodology

The steps involved in the execution of the proposed work are image acquisition, preprocessing, feature extraction and classification which are explained in the following section.

3.1 Image Acquisition

"In image processing, the image acquisition can be defined as the process of retrieving the image from different types of sources." The hardware-based sources are used to retrieve the images. Performing image acquisition is always the first step in image

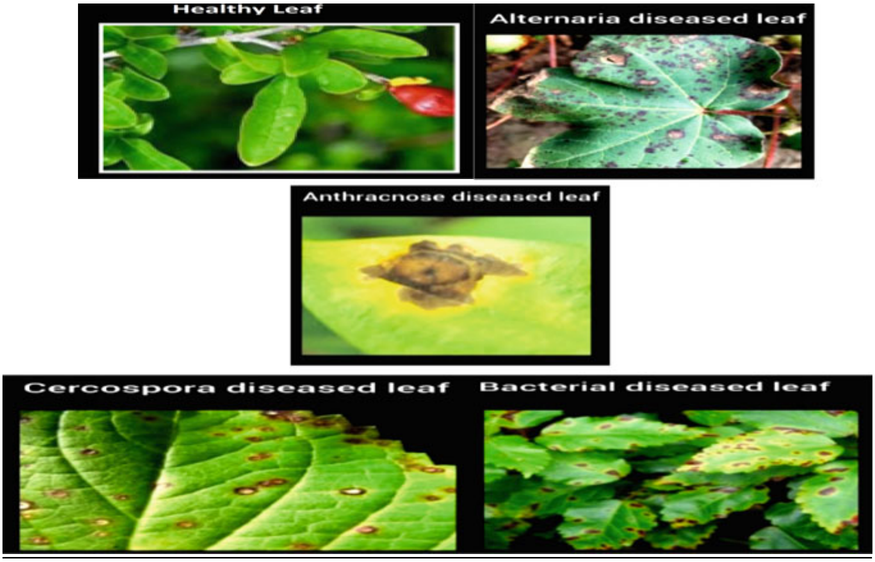

Fig. 2 Sample images of healthy and disease leaves

processing, because without an image, further, any processing is not possible. In the proposed method, the images are collected from farms, agricultural universities and books and data available on the website (which is publicly available) to prepare own database for healthy training of the system. The database contains the disease-affected leaves and healthy leaves.

The leaf has four different diseases. They are alternaria, anthracnose, bacterial blight, cercospora. The sample images of pomegranate plant leaves are shown in Fig. 2.

3.2 Preprocessing

The image set obtained from the dataset consists of noise. Noise may be dust, spores, water spots, etc. So images must be preprocessed to remove the noise. After preprocessing, the image should be resized to adjust the pixel values. Then it enhances the quality of the image with respect to contrast.

Try searching for the threshold that minimizes the intra-class variance [15], defined as a weighted sum of variances of the four classes:

$$\sigma_\omega^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) + \omega_3(t)\sigma_3^2(t) \tag{6}$$

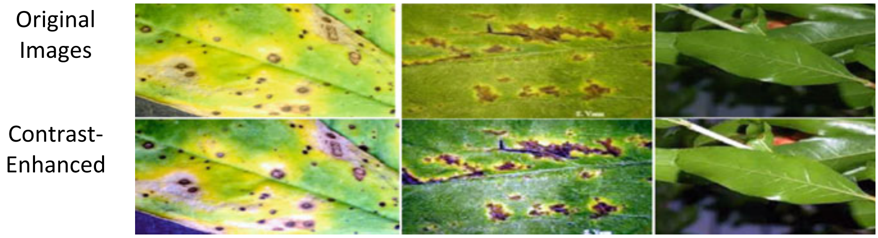

Fig. 3 Sample images after contract enhancement

Weights ω_0, ω_1, ω_2 and ω_3 are the probabilities of the four classes separated by a threshold t, and σ_0^2, σ_1^2, σ_2^2 and σ_3^2 are variances of these four classes. Then class probabilities and class means can be computed iteratively.

Apply morphological operations on the image (Fig. 3).

3.3 Feature Extraction

In the segmentation stage, the preprocessed image is given as an input. The segmentation means subdividing the whole image region into small regions. In the proposed method, k-means clustering algorithm is utilized for the segmentation process [11]. It is useful to extract the image structures.

In the proposed system, the k-means clustering intends to partition n perceptions into k-clusters in which every perception has a place with the cluster with the nearest mean, serving as a model of the cluster. Clustering is the process of portioning a group of data points into a small number of clusters. The following objective function (Equation 7) narrates the same.

$$\sum_{i=1}^{k}\sum_{x\in S_i}^{k}||x-\mu_i||^2 = \sum_{i=1}^{k}|S_i|\text{Var } S_i \tag{7}$$

where μ_i is the mean of points in S_i. This is equivalent to minimizing the pairwise squared deviations of points in the same cluster. For instance, the pixels in the image are clustered. Of course, this is a qualitative kind of portion. Figure 4 shows the example of the k-means clustering.

Thus, the steps involved in segmentation process using k-means clustering operation are

Input: Leaf image.
Output: Segmented clusters of leaf image.
Step 1: Find the centroid of the pixel.
Step 2: Divide the pixels into a cluster.
Step 3: Represent the clustered image.

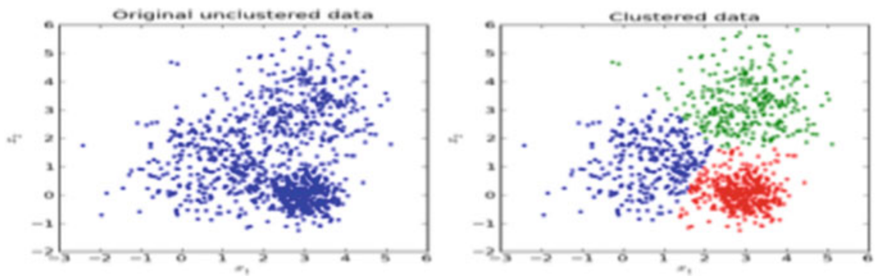

Fig. 4 *K*-means clustering. *Courtesy* https://qph.fs.quoracdn.net/main-qimg-770e75d8c69d0b77f49bb371cad50c3d

Step 4: Segmented output (Fig. 5).

In the proposed strategy, the segmented image is utilized to extract the characteristics of the input image [12]. To extract the region of interest, the estimation of these characteristics is essential [14].

The features extracted from the segmented images using GLCM are further utilized for the classification.

Thus, the process for statistical feature extraction is:

Input: Leaf image
Output: Statistical features
Step 1: Read the segmented leaf image
Step 2: Calculate the features by applying the GLCM technique
Step 3: Generate a feature vector.

In the proposed technique, statistical features like mean, standard deviation, entropy, skewness, kurtosis, correlation, etc. of segmented image ought to be superimposed to the sample image. All extracted features of the sample image are compared to the feature set of training images which were extricated and stored in characteristics or feature table (Fig. 6).

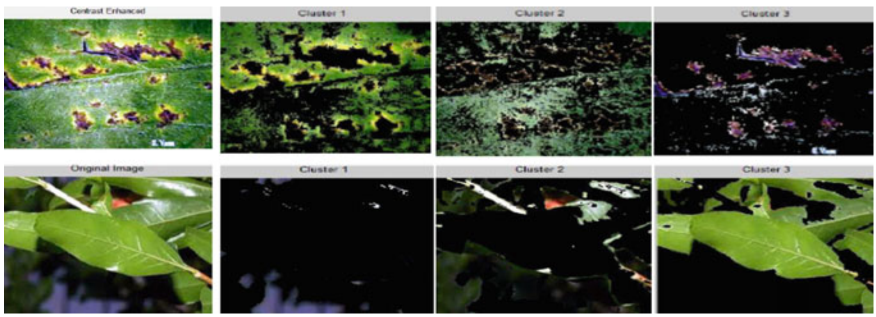

Fig. 5 Sample images after clustering

Mean	S.D	Entropy	RMS	Variance	Smoothness	Kurtosis	Skewness	IDM	Contrast	Correlation	Energy	Homogeneity
0.078876	0.978321	0.762589	0.974878	14.84385	47.81168099	1.709878	5.5747726	2150.696	1	15.597769	3.632011	255
0.466835	0.865708	0.796721	0.959196	14.15012	48.13958466	1.365848	4.3136177	1632.216	1	15.765401	3.674427	255
0.367586	0.910197	0.757318	0.962547	16.44411	51.41942893	1.667891	5.340374	2305.041	1	13.792639	3.402522	255
0.541238	0.751034	0.538239	0.922202	17.97166	37.66351987	2.582884	7.4036979	1306.813	1	10.495102	2.588339	255
0.512776	0.710321	0.894702	0.971681	17.1185	35.52045275	2.843172	10.450455	1162.225	1	27.603284	4.682011	255
0.697626	0.873892	0.487259	0.910412	31.56037	56.45960734	2.982981	8.114045	2844.325	1	4.4008361	1.612926	255
0.488618	0.958014	0.268706	0.940314	71.85277	83.0728783	5.120415	11.461609	5682.676	1	1.8269994	0.649677	255
0.430913	0.896565	0.765986	0.965598	17.43762	52.46393422	1.878881	5.7288992	2052.447	1	12.8361	3.273623	255
0.576072	0.909153	0.710405	0.958389	23.81361	60.20882544	1.673428	5.4362373	3230.313	1	6.958173	2.334859	255
0.746201	0.90982	0.52789	0.900746	40.04733	73.85749163	2.911928	7.5330257	4465.177	1	3.9931523	1.587334	255
0.88943	0.826304	0.818493	0.96507	16.41812	55.65340939	1.300243	4.3227964	2841.536	1	12.320378	3.301014	255
0.413971	0.970172	0.410585	0.972992	76.61838	97.98214573	3.843924	9.3641523	6332.289	1	1.5171447	0.599022	255
0.08629	0.94908	0.884848	0.993442	8.575495	35.45269477	0.717587	2.5151335	1110.396	0.999999	18.75243	4.105919	255
1.045052	0.816676	0.619172	0.920878	26.94916	60.87399316	2.481799	6.9559693	3471.252	1	6.6287909	2.20753	255
0.413097	0.845948	0.842361	0.976562	10.60321	41.47241151	1.194491	3.8288648	1594.445	1	22.346086	4.420793	255
1.006648	0.795249	0.796001	0.954265	16.59695	54.72505252	1.297603	4.6008753	2771.884	1	12.37107	3.282577	255
1.319761	0.864802	0.480227	0.919423	44.17804	76.8477228	3.321984	8.6894848	5494.231	1	3.411599	1.430894	255
0.27454	0.870993	0.859583	0.979117	9.741954	38.48165041	0.886391	3.5148447	1388.821	0.999999	19.345475	4.109354	175
0.565518	0.869229	0.673009	0.954929	21.60405	53.86948886	2.322427	6.2055053	2484.706	1	9.9313647	2.734996	255
0.262546	0.879222	0.798925	0.976501	13.27572	42.41367953	1.271065	4.3010873	1614.019	1	12.961897	3.281804	255
0.331847	0.866178	0.734424	0.957452	18.0845	41.43077451	3.817042	9.7439957	1158.825	1	22.607484	4.280236	255
0.841958	0.763881	0.704448	0.935609	18.29885	47.74902051	3.338588	7.1460656	2201.596	1	13.609027	3.268961	255
0.41152	0.981417	0.350451	0.94482	128.9061	118.6973325	3.6237	12.574377	10666.31	1	1.0988286	0.015921	255
0.667126	0.916899	0.480335	0.911658	41.22886	71.50431469	3.270195	8.1946567	4609.107	1	3.8336729	1.502789	255

Fig. 6 Characteristics or feature table

A mid-training phase the feature vector is stored as a text file and it is called as training data. The text file itself is utilized as a contribution for the classification. In the training stage, all the images are named utilizing the 0, 1, 2, 3 and 4 rotations. 0 represents the alternaria disease leaf. 1 represents the anthracnose disease leaf, 2 represents the bacterial disease leaf, 3 represents to cercospora disease leaf, 4 represents the healthy leaf. A mid the testing stage all the measurable features are extracted for the given image and stored as a text file and text data.

3.4 Classification

In the proposed strategy, the support vector machine (SVM) classifier is utilized. In a high or boundless dimensional space, a machine builds an arrangement of hyperplanes that are utilized for classification. Here, the margin is being looked to maximize between the data points and the hyperplane [13]. The loss function that will maximize the margin is given by

$$c(x, y, f(x)) = \{0, \text{ if} y * f(x) \\ \geq 11 - y * f(x), \text{ otherwise} \tag{8}$$

The hyperplane is accomplished the great partition if preparing information purposes of closest separation to any class having the biggest separation. If classifier having the larger margin, then generalization error will be low. In the support vector, the data points are near to the isolating hyperplane. By definition, "*x*" representing the data points of sort 1 and "−" representing the data points of 2. For a given training set, every value is named as having a place with one of class. It builds a model and new cases will be dispensed to one of the classifications. The illustrations are represented as points in space in Fig. 7.

Essentially, SVM can just resolve issues which are identified with double characterization. Presently, they have been extended to prepare multi-class issue. It utilizes the one after one strategy to fit all paired subclassifiers furthermore to locate the right class by choosing component to concede the multi-class order. The workflow of the proposed system is depicted in Fig. 8.

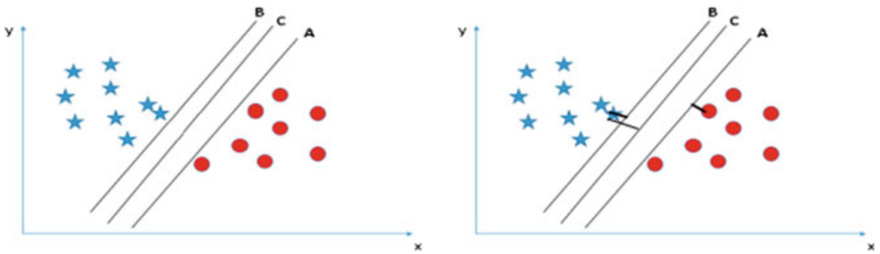

Fig. 7 Support vector machine

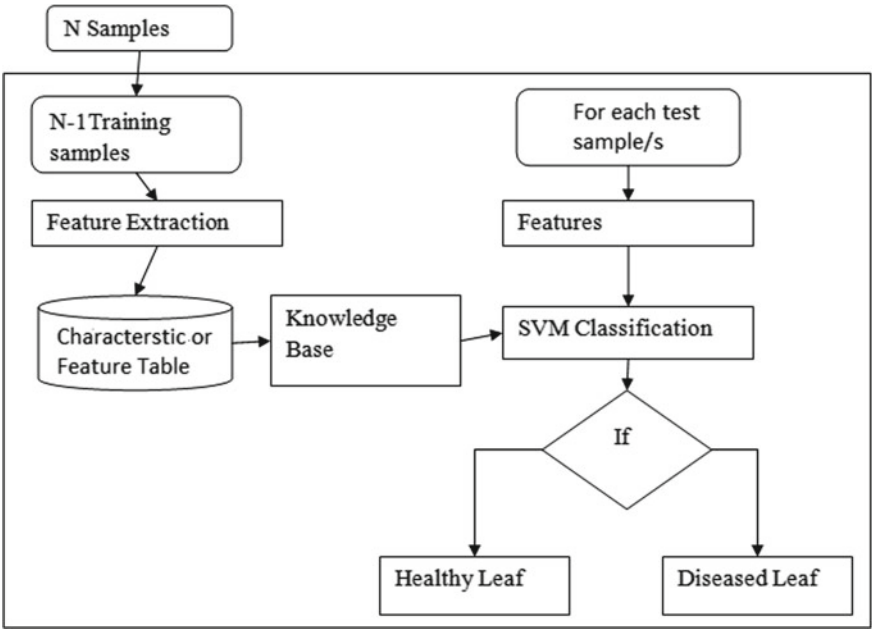

Fig. 8 Block diagram of classification

4 Experimental Results

The proposed method comprises of 125 pictures; the projected strategy utilizes the fundamental features like mean, standard deviation, skewness, kurtosis and many more. These features are put away in the feature or characteristic table as shown in Fig. 6. This table is acting as a reference of knowledge for the SVM classification.

The extracted characteristics or features of the segmented sample input image are given as an input for SVM classifier for the classification. In view of these qualities, it will classify the leaf as healthy and diseased. After classification, the results are directed with the assistance of performance parameters like specificity, sensitivity and accuracy. Taking into account, these values can without much strength legitimize the accuracy of the classification.

4.1 Performance Parameter

The dataset comprises of both diseased and healthy leaf images. The test results can be positive means; it predicts the image as a diseased leaf. On the off chance that the test result is negative means, it predicts the image as a healthy leaf. The different testing results are:

- True Positive—the segmented leaf is healthy or diseased and it is classified as healthy or diseased respectively.
- False Positive—the segmented leaf is healthy and is classified as diseased.
- True Negative—the segmented leaf is diseased and is classified as diseased.
- False Negative—the segmented leaf is diseased and is classified as healthy.
- *True Positive Rate*: It is additionally called as affectability. It decides the extent of real positive values that are accurately distinguished. It implies that the rate of the segmented leaf containing diseased is effectively classified as diseased.

$$\text{True Postive Rate} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{9}$$

- *True Negative Rate*: True negative rate is likewise called as specificity. It decides the extent of negativity qualities which are accurately recognized. It implies that the rate of a healthy segmented leaf is effectively delegated healthy.

$$\text{True Negative Rate} = \frac{\text{TN}}{\text{TN} + \text{FN}} \tag{10}$$

4.2 Accuracy

It decides the factual measure of how well a classifier has effectively classified the images. The accuracy is the rate of genuine after-effects of both true positive and true negative qualities.

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TN} + \text{TN} + \text{FP} + \text{FN}} \tag{11}$$

The classified results are shown in Fig. 9. The accuracy and error rates for SVM polynomial using a confusion matrix with a various ratio of training and testing dataset are depicted in Fig. 9. The accuracy of the stated SVM is ranging from 84 to 88%.

The scatter plots for the various training and testing dataset ratios with one feature (Mean vs. Correlation) to the confusion matrix are depicted in Fig. 10.

The affected areas of the various leaves with different types of diseases in percentage are depicted in Figs. 11, 12, 13 and 14.

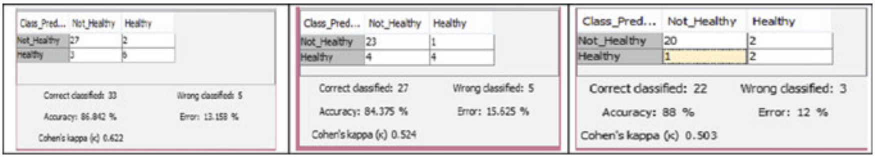

Fig. 9 Confusion matrices with accuracy and error rates for different training and testing ratios (70:30, 75:25 and 80:20, respectively)

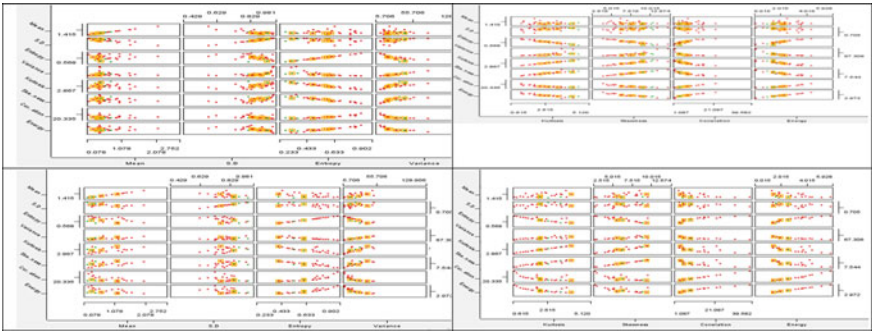

Fig. 10 Scatter plots with the misclassified highlighted for different training and testing ratios (75:25 and 80:20, respectively)

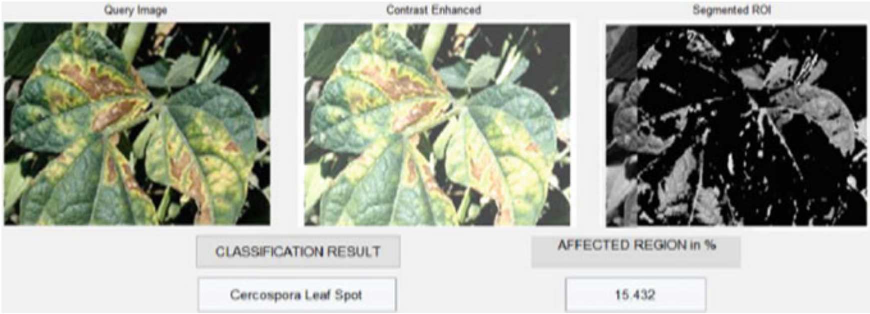

Fig. 11 Cercospora diseased brinjal leaf with 15.432% affected

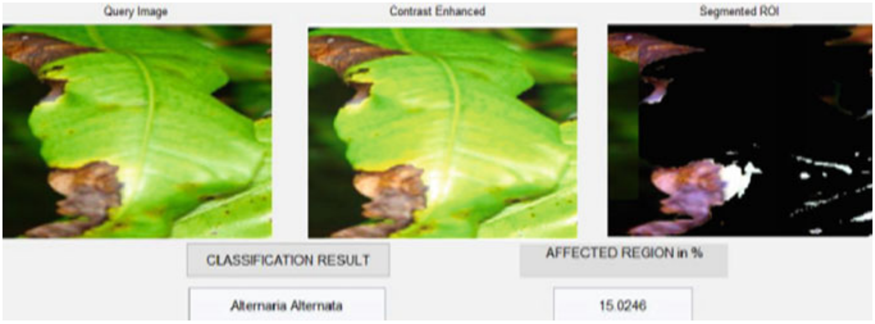

Fig. 12 Alternaria diseased mango leaf with 15.0245% affected

Fig. 13 Anthracnose diseased cotton leaf with 15.773% affected

5 Conclusion

This work proposes the development of diagnostic classifier for leaf images of the plant. Usually, plant images are having noise. Therefore, it is necessary to improve the contrast and suppress the noise present in the image, for identification of diseased leaf of a plant. The enhancement technique is used to improve the contrast of the images; it removes the noise present in the image. After the enhancement technique,

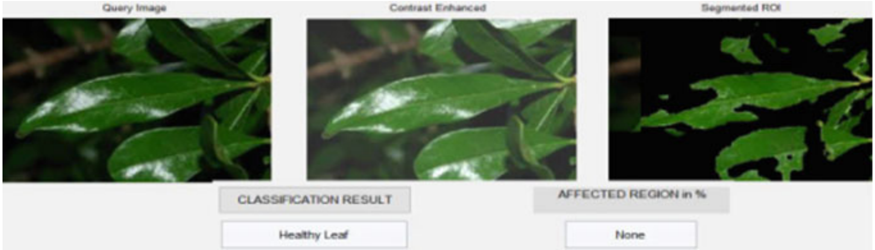

Fig. 14 Normal and healthy pomegranate leaf

the images are segmented using a *k*-means clustering algorithm. The segmented images are used for feature extraction and have utilized extracted relevant data about the segmented images for the classification. Support vector machines are used to analyze data and recognize patterns with the assistance of algorithms and accuracy of the result obtained is quantifiable up to 88%.

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